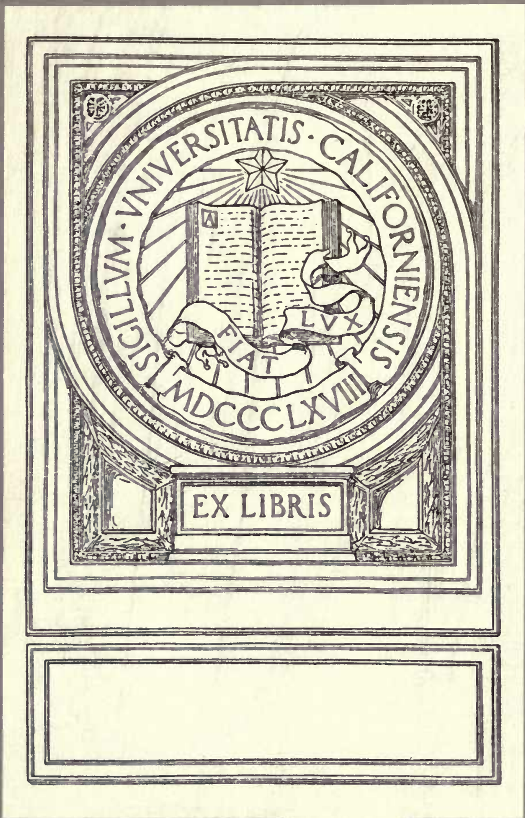
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Gorge in the Old Red Sandstone, near Gilboa.

E. B. Walsworth

MANUAL

OF

GEOLOGY:

DESIGNED FOR THE USE OF

E. B. Walsworth

COLLEGES AND ACADEMIES.

BY

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Illustrated with numerous Engravings,

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ment of rocks on this side of the Atlantic agree with those upon the other. But inasmuch as we now have an American geology, let it be taught. It is for our interest to make foreign geology subservient to American. But we need not dwell on this subject.

One of the most important studies for the young is *classification*. Its advantages are not confined to natural history. In every sphere of knowledge it aids the mind to define and limit the boundaries of subjects, and perceive the true and constant relations they hold to each other.

Our opinion of its utility led us to furnish an introduction to the subject, which, though imperfect, may still, as we believe, serve as a basis upon which classification may be taught.

The plan we have followed in the preparation of the work differs somewhat from others. We have given in each chapter treating upon the systems of rocks, a general history of the period to which they belong. To this we have added a brief description of the rocks and their order of sequence. Each system is illustrated by the organisms or fossils which it is known to contain, and which have been generally selected from those which are the most common. The geographical distribution of American formations completes the history of the several systems.

Our illustrations of characteristic fossils may be regarded by some persons as out of proportion to the statement of facts and principles; but it should be recollected that *Palæontology* has become the leading branch; and from which we derive the most important information respecting the natural history of the earth.

This feature of the work gives the general reader, as well as the student, an opportunity to form a correct idea of the progress of life upon the globe; and will enable him to contrast the palæozoic with the cainozoic age, from which he will perceive the high standing of the organisms of the latter, when compared with the former.

Geology is comparatively a modern science, and it cannot

be supposed that its doctrines will not require modification from time to time. Of this we are able to recall many instances. But with this admission we feel that it has already established a body of well settled principles, deduced from well determined facts and observations. These principles constitute a sure foundation, upon which is being reared a noble superstructure. Its progress has been in no respect different from other sciences. Chemistry had its alchemistic age, and geology its cosmogonists, but this fact does not diminish its importance, nor should it cast doubts upon its conclusions.

We are confident we are safe in the foregoing opinions, notwithstanding there remains a slight leaven of the old cosmogonists. The fact is, some geologists belong naturally to this order of men, and *geology proper* would be too tame and spiritless, if it were not that some of the crust movements permit them to be converted in imagination into overwhelming convulsions.

In treating those subjects which required a place in this work we did not deem it necessary to discuss them to exhaustion. Much may have been said, which has been omitted. It is frequently enough to bring the subject up, and leave the discussion of it to the teacher.

It is probable that our own views upon certain geological points may differ from those entertained by distinguished men. Where the discrepancies of views are worthy of note, they have been stated and maintained in this work; because we have reason to believe that our opportunities for forming a correct one have been better than those from whom we differ, or because we have taken special pains to be rightly informed upon the subject, *and hence* have a legitimate right to an opinion.

The present advanced state of geology demands a certain amount of information in the collateral sciences, *chemistry*, *botany*, and *mineralogy*. In the order of study the collaterals stand first. To become an accomplished geologist

requires a considerable amount of field information derived directly from observation. Collections should always be made and notes taken upon the spot, detailing all the important phenomena a locality may furnish. It is the only mode by which remunerating results can be obtained.

RALEIGH, May 1, 1859.

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MANUAL OF GEOLOGY.

CHAPTER I.

KNOWLEDGE AND ITS DEPARTMENTS.—CHARACTERISTICS OF MAN AND THE PROGRESS OF KINGDOMS.

1. The sum and substance of all knowledge is derived from the observation of Phenomena, and whatever we know of matter or mind, becomes our property through phenonema; or, what may be regarded as expressing the same thing, is ours, through and by associated facts of which we become conscious by our mental operations.

Knowledge becomes Science, when the phenomena of existence are so far known, that they may be classified; or when they are so far known to us, as to enable us to express ultimate results or fixed relations.

Mind, is that which thinks and wills and is also emotional; Matter, is that which is known to us through the medium of the senses; and hence, knowledge is divided into two great departments: one relates to *Material* bodies, and the other to *Immaterial* existences. These constitute the two great fields of human research; the first is usually called *Physical*, and the last *Metaphysical* science. Both however, are prosecuted through and by the intervention of phenomena, and belong equally alike to existences in nature. They include together the facts of all existences, but are properly separated as their fields are dissimilar in kind, though both are concerned with phenomena and cannot be investigated without them.

2. Physical Science, usually called *Natural Philosophy*, takes in its domain all the phenomena of external nature, or all substance which

is recognisable by our senses. But its domain is so wide, that it becomes necessary to subdivide the field into minor areas, each of which comprehends distinct and separate branches of science. These have received appropriate names, which have been applied according to the nature of the subject-matter they include.

The first and most comprehensive division is based upon the presence or absence of the principle we call *Life.* This leads us to form two great divisions of matter, one of which is called *Organic* and the other *Inorganic* matter.

3. The phenomena of organic bodies are comprehended under the terms *Zoology* and *Botany.* They are also called Kingdoms. The former includes in its domain, the associated facts which relate to *Animals,* and the latter, those which relate to *Plants.*

4. Inorganic matter includes in its field all that belongs to the earth and heavens, not included in the former divisions; it therefore comprehends Astronomy, Geology, Mineralogy, Chemistry, &c., together with the consideration of those forces which belong to each respective department; or, in other words, the laws of celestial and terrestrial bodies.

5. Geology comprehends in its domain all the facts concerning the relations of the masses which compose the Earth, its structure, and the changes it has undergone in time: but a fuller statement of its objects will be found farther on.

6. Mineralogy treats of the individual objects which compose the earth, and the characters by which they may be known.

7. Chemistry has a special reference to the Composition of bodies, and the laws of Combination to which the elements are subject. It determines what bodies are Simple, and what are Compound, and in what ratios the elements combine.

8. Palæontology combines in its domain the associated facts relative to Fossils, whether of vegetable or of animal origin, which are found in the sediments or rocks of aqueous origin.

9. The earliest condition of the foregoing branches of knowledge was in that of isolated, or of disconnected facts. Their reduction to order and combination into a scheme expressing general and fixed relations, elevated these facts into departments of science.

10. Facts are accumulated by two methods, *Observation* and *Experiment;* but their arrangement and construction into systems is by a process called *Induction,* the facts and experiments consti-

tuting the basis by which the inductive process is executed. This process is generally defined, as that by which general laws are inferred from particular facts. The induction itself expresses the general result or law which is established from the consideration and bearing of the facts observed.

It is evident, furthermore, that results or laws require in us a belief in the uniformities of nature; or that like causes are followed by like effects. Without such a belief, or unless these uniformities existed, science would be impossible. Science, we may therefore state, is founded upon the uniformities of nature, without which our observations would be of no avail, and our experiments would be useless.

11. The explanation of effects is accounted for, in general, by referring them to something which, so far as we know, constantly precedes them; and that which precedes, is said to be the cause. But, then, it is customary to speak of two kinds of causes, *Physical* and *Efficient*. The former is the *law* itself, as the fall of a stone to the earth is referred to the law of gravitation. The latter implies intelligence, and is referred directly to the Divine will.

12. In investigating the facts of all existences, it is necessary to recognise the presence of both forces and agents. It is by them that the uniformities of nature are usually expressed. What is called *Gravitation* is an example of an universal force, and the law of the movements of bodies is expressed by well-known formulas, while *Affinity* is a force which affects the molecules of matter, and disposes them to combine in definite ratios.

13. Agents are physical bodies.—In geology, for example, it is necessary to recognise the agency of fire and water. Their effects become evident to the senses, and their operations are extremely varied. The action of particular forces is inferred from effects or consequents.

14. The kingdom of inorganic matter stands out prominently by itself, and is evidently subjected in itself to the action of physical forces only. These are its highest endowments. The first step indicative of progress, is in the vegetable kingdom, or in the domain of organic matter. Here, life in a low degree is engrafted upon organization, or is associated with it, and may be the formative principle of organization. It exhibits a great advance upon inert matter, especially when contrasted with the law of inertia. Thus the lowest condition of life appears first in the vegetable kingdom,

where it is designed in part to evolve successive generations of beings, to clothe the earth, and furnish a supply of food for animals. The life of the vegetable kingdom is called *Vegetative* life; it is simply nutritive in its functions. Another stage far in advance of this is *Animal* life; a concomitant of animals. By this kind of life, the world of matter becomes known to us through the medium of the senses. Vegetative life is a blank, or is blind. But animal life may be said to be engrafted upon what previously existed; for vegetable life still works in animals in the nutrimental sphere, precisely as it does in vegetables. There is nothing, therefore, in the advance of kingdoms which is deposed. We also see that the advance of kingdoms is not by *Differentiation*, but by *Incrementation*. The latter expresses the law of progress in the kingdoms.

15. The highest concomitant of animal life in itself is *intellect*, embracing the knowing faculties, which are dispensed in different degrees, and are common to animals and man. But the crowning stage is exhibited in the sphere of man *alone*, for there is engrafted upon vegetative and animal life and its concomitant Intellect, *Reason*, and *Conscience*, with their concomitants also, which confer upon man the highest boon, immortality.

16. In all the foregoing stages of progress, nothing is deposed or dethroned. The physical forces, it is true, are for the time being overridden, but not left out. Vegetative life still performs its office in its own sphere. Intellect in man, though of a vastly higher grade than in animals, maintains its place, and the highest attributes we have named are the governing characteristics by which he should be classified. These, *reason* and *conscience*, are the attributes of his sphere, and place him above, and out of the pale, of the so-called animal kingdom. The life of reason and its concomitants, being engrafted upon the intellectuals, if progress is truly expressed. exhibits the kingdoms as completing their progress in four stages; advancing from the inertia of matter, through vegetative life, to animal life and its engrafted concomitants, then upward to the life of reason in the soul of man, becoming thereby the true characteristics of his being.

17. These stages are recognised in the geologic periods, and correspond with the succession of vegetables, animals, and man upon the globe: the kingdom of matter first, the kingdom of man last, the extremes of the geologic scale.

CHAPTER II.

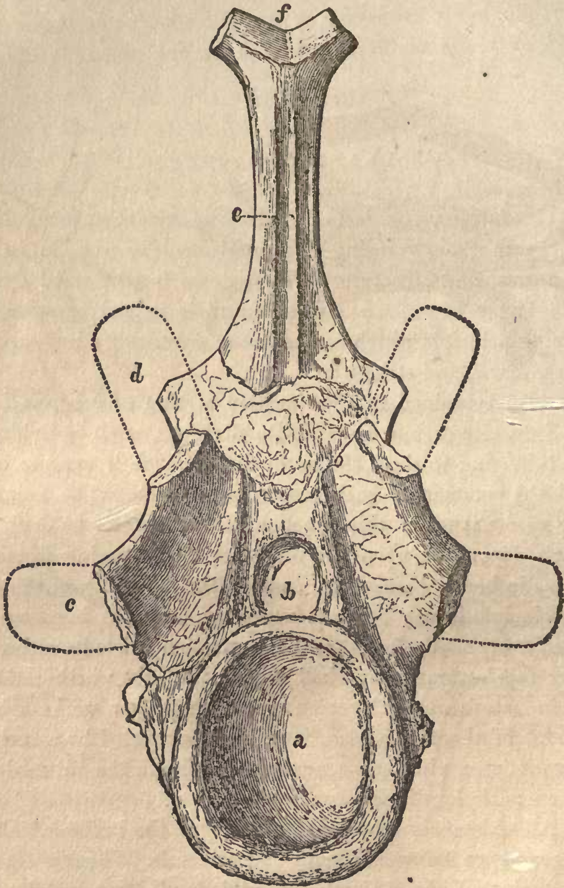
CLASSIFICATION.

18. CLASSIFICATION is the Systematic Arrangement of bodies, according to the governing characteristics discoverable in their plans, forms, and structure. The process is performed daily by men in virtue of their possessing in their mental organization a classifying principle which can seize the governing ideas expressed in plans, forms, and structures.

The idea contained in Classification is that of a separation of bodies into classes and subordinate divisions, each individual of which belonging to those classes or divisions, shall express one or more ideas common to each respective division. The foundation for the performance of this function, it can scarcely be doubted, is as much dependent upon the existence of governing forms and structure in bodies themselves, as upon the possession of the classifying principle in us; both are necessary, and it is important that we should especially feel that the foundation exists in nature; for without this assurance we shall remain in doubt whether there is really in nature a regular plan upon which her works are constructed. If there is a plan, it will be manifested by a series of characteristics or phenomena, expressed either in the outward form, or their less obvious inner structures.

19. All existences may be classified, but the bodies which concern us most are Animals, Plants, and Minerals. These if classified are denominated the Animal, Vegetable, and Mineral Kingdoms Each kingdom has its own principles of classification, notwithstanding the heads of the divisions are designated alike in case the divisions are admissible or founded in nature. Taking the animal kingdom first, as it furnishes the best illustration of a scheme of classification, it has been determined that there are *four* diverse branches or plans which were created to express so many modes of life which are compatible with the reigning external conditions of the globe. Each *branch* circumscribes all those existences which are constructed upon a certain plan.

Fig. 1.

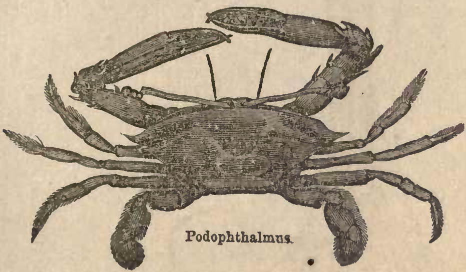


Vertebra.

20. These plans are expressed by the following terms. 1. VERTEBRATA. 2. ARTICULATA. 3. MOLLUSCA. 4. RADIATA. It should be understood that these are not modifications of one plan, but that they are four distinct plans; and to determine whether a being belongs to *Vertebrates* (fig. 1), we have only to inquire whether it has a *Spinal* cord, or if to the *Radiata*, whether its organs are arranged *radiately* or not. Respecting the first, we need not institute an inquiry as to the conditions of the protecting organ, whether it is bone, or a cartilaginous tube; the inquiry is, *whether it has the*

nervous organ, the spinal centre, or not. In the latter, the question is not put whether it has nerves or not; but simply into the *radiate disposition of its organs.* With respect to the *Articulata* (figs. 2 to 4,)

Fig. 2.



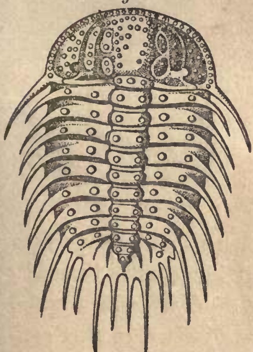
Podophthalmus.

Fig. 3.

Lytta vesicatoria.

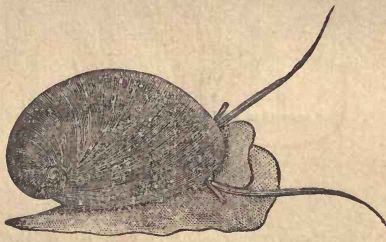
Articulata.

Fig. 4.



Articulata. Acidaspis.

Fig. 5.



Mollusca. (Nerita Polita.)

whether it has a jointed body and limbs, or of *Mollusca* (fig. 5), whether its body is soft, having a peculiar flesh like the oyster. Other inquiries are extraneous when the branch to which an animal belongs is the only question for determination. From the foregoing remarks it is evident that a branch of the animal kingdom has reference solely to a plan, but not the details of a plan.

The figure of the *Lacamedea geniculata* (fig. 6, p. 20), from Johnson, shows both the closed and expanded vesicles of the polype, and also the radiated arrangement of the parts of the animal. They produce in growth a corneous stalk which puts forth buds something in the form of a flower. It represents one of the orders of this

great branch of the animal kingdom *Radiata*. In another type, the asteroid, the polype forms a stony skeleton, which is known under the common name of coral; Fig. 7 represents this order, which also belongs to the branch Radiata.

Fig. 6.

Lacamedea geniculata.

Radiata.

Fig. 7.

Corallum rubrum.

21. Regarding, then, the foregoing statements with respect to the four plans of organization of the animal kingdom to be established, we may proceed to the consideration of *Class*, which is the next division below that of branch. The word class, in this connection, means the highest and most comprehensive division which can be made in each respective branch. It is important to observe here, that the characters which are employed should have reference to the plan of structure, and be selected with a view to express the mode by which Nature executes or carries out her plan of organization, whether it be a vertebrate, or any other plan belonging to the kingdom. In each class, provided there is an harmonious system of construction, we shall find a ruling idea expressed in structure, or in the economy of their systems, which will run through the entire class, and in which we shall find an unmistakable similarity or homology in each member, however much it may seem to differ in form

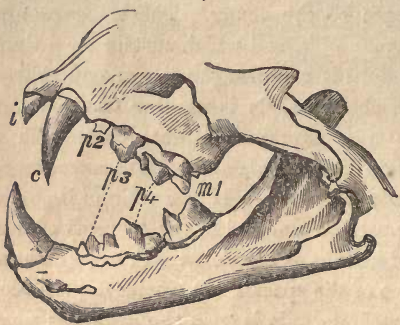
In the first place, we propose to illustrate the preceding principle

by the Vertebrata. This branch, as now constituted, contains five classes: Mammalia, Aves, Reptilia, Amphibia, and Pisces. These have one characteristic; all have the spinal cord. Now, on what grounds are these classes established, or by what characteristics are they so circumscribed that we have a right to distinguish them as classes? We may demonstrate their right to this distinction and standing by the following characteristics: And, firstly, by the mammals.—In this group, a system of organs has been provided for the temporary subsistence of the young. These organs are lactiferous glands which secrete milk, and which sustain for a time the newborn individual, or until it acquires the power and ability to provide for itself. This characteristic is wanting in the other classes. The name of the class expresses its characteristic in a condensed form. The selection of this characteristic is in accordance, too, with the principle already laid down It is a ruling idea, or a class character, being universal and essential in the economy of this great division of beings; and besides, is associated with organs whose office secures the continuance of the species. It carries out the economy of the plan of the vertebrata. It is true, the mammals wear hair upon their skin, but this is a circumstance; they could subsist without it; but milk glands, with their appendages in this plan of organization, are made to express the most important idea of the class.* But the idea of the class is founded upon soft parts which

* In one sense it is not the activity of the milk glands which constitutes a mammifer, for the individuals of this great family are *born mammifers;* they are so prior to the time when they become essential elements in the animal economy. When we speak of *predominating organs* or *elements* in the structure or economy of living beings, our meaning is, that they are common or constant to the individuals composing the branch, class, order, etc., in the adult state. Perhaps we might justly say, that which constitutes the essentials of a being is invisible, and inappreciable to our senses. The principle in the egg of a fowl, which evolves the fowl, is inappreciable, and is not dependent upon organs, because that would place the effect before the cause. The egg of a fowl evolves a fowl, and not a reptile, because it receives the principle which evolves it from the parent, and we can go no farther than to say that it is the gift of the CREATOR. The Creator imparted to each species its *specific force*, inappreciable to us, by and in obedience to which each definite species is evolved in its sphere, and this gift secures the permanence of species for all time, and prevents their coalescence; while at the same time they possess certain flexibilities of character which enables them to conform to a range of circumstances which it was foreseen they would be subjected to; and hence these *variables*, as they may be called, are a part and parcel of family or of their specific characters.

never exist in fossils; hence it is necessary to know more of the organization of mammals than it is possible to learn from the soft parts alone, and we must find in their bones those characters which belong to them as a class. Such characters exist and become available for this purpose; for example, the lower jaw of all mammals is in one solid piece, as seen in fig. 8. Whereas, the jaws of reptiles and fish are composed of many, as in fig. 9; besides—

Fig. 8.



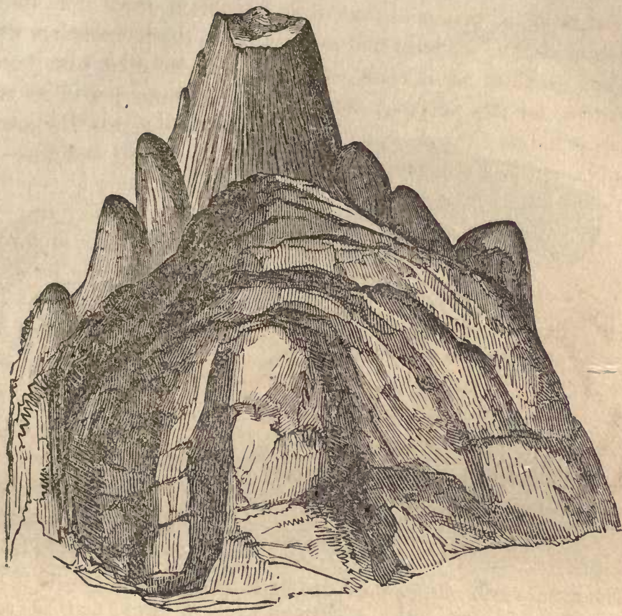
Skull and Jaw of the Tiger.

Fig. 9.

Jaw of an Alligator, with its sutures separating its pieces.

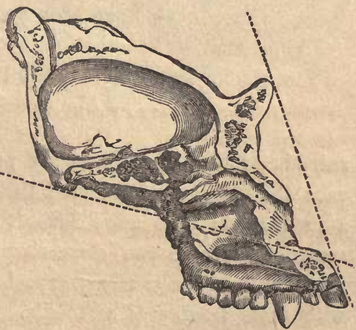
The molar teeth of mammals, too, have more than one root. Fig. 10 (see p. 23). Indeed, it is doubtful whether the *reptile* has molars at all, since the back teeth have only one root. (Fig. 9. A large back tooth elevated to show that it has a single root, as at *a*.) From the foregoing facts it will be seen that some of the details of the classes which lie at the foundation of the great divisions of the branches, exist both in the soft and hard parts of animals. The Zeuglodon (fig. 10) has a sauroid form, and was taken for a saurian when first discovered; yet its teeth, from their double roots and the convexity of its condyles, prove it to be a mammal. In the highest mammals there is always a complete series of molars, pre-molars, canine, and incisor teeth, as in the Chimpanse (fig. 11). There is also a wide space between mammals and birds. The latter have mandibles and no teeth: fig. 12 (see p. 24); the mandibles

Fig. 10.



Zeuglodon Tooth with its double roots.

Fig. 11.

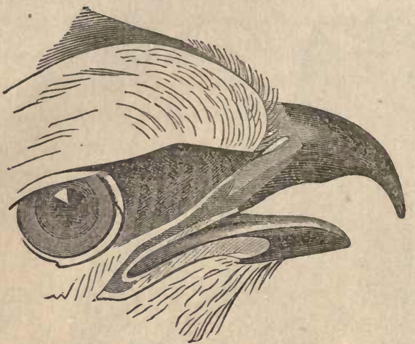


Chimpanse.

of the eagle, or fish hawk; but we know a family of mammals in New Holland which have the mandibles of a bird; but their feet differ from birds, and hence we take into consideration the character of the feet (fig. 13, p. 24). It would occupy too much space to go farther into particulars and point out differences between the Monotremata and birds.

It is more difficult to find marks which distinguish reptiles, amphibians, and fishes, especially when we possess only organic remains. True reptiles, however, have only one condyle, whereas the amphibia have two (fig. 14, p. 25). A. showing the base

Fig. 12.



Mandibles of the Fish Hawk.

Fig. 13.

Foot of the Fish Hawk.

of the skull of the Dictyocephalus, a reptile which belongs to the Labyrinthodonts, all of which have also double condyles.

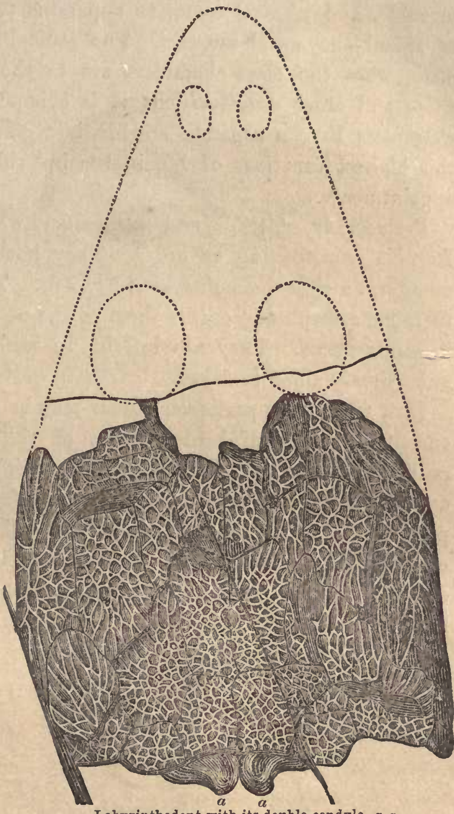
Their bones, however, differ in structure, and under the microscope the remains of fish may be distinguished from reptiles by the form of the bone cell, which will be noticed farther on.

One of the distinguishing characters of amphibians is their naked skin. They have neither scales nor plates, and besides they undergo a kind of metamorphosis which is unknown in the other classes. There is little difficulty in classifying animals as they are commonly presented to us. We may see at once the difference between a fish and a lizard or frog, a bird and a quadruped; it is more difficult to point out distinguishing characteristics where two classes approach each; or in the sauroid fishes, and certain saurians, especially where the student has to deal with mere fragments of fossils. These require careful study, and we have no space to devote to specialities of this kind.

22. Order takes the next rank below class. It is a subdivision of classes, and hence, it would be an error to employ those characters which relate to the mode in which a plan of structure is carried out. It derives its characteristics from the details of the

general organs, or the differences existing among them in each class respectively. For illustration, we may cite the class Reptilia—a scale-bearing, and at the same time an air-breathing vertebrate. The class contains animals whose bodies are protected by a box or shield above and below, connected laterally by a bridge. These form one order in the class, and are named the *Testudinata*, or turtles. Another group of reptiles, that of *Sauria*, have elongated bodies, and a mouth furnished with teeth; and another, Ophidia, with vermiform bodies and destitute of feet, or who employ their ribs as a locomotive apparatus. All these modifications of structure illustrate modes in which the orders of the class differ; which differences constitute a basis for the establishment of the orders themselves.

Fig. 14.



Labyrinthodont with its double condyle, *a a*.

The ordinal characters being modes of expression, by which the class arrangements are carried out, we can scarcely fail to observe that they necessarily lead to many details of structure which are truly ordinal also. Thus, in the turtles, an important modification of the muscular system follows from the peculiar protection of the shield: no movements are required of the spine except of the neck and tail; and those of the neck are executed in a mode quite peculiar. On the contrary, the extreme of the muscular arrange-

ments exist in the serpents, whose spinal column is extremely movable, and whose locomotive apparatus requires a combination of spinal and costal muscles. The ordinal characters are to the class, what the class characters are to the branches; and from these and other considerations it is evident, that as the ordinal characters have a separate and distinct office, or indeed perform the highest functions of life in the individual; they are natural appointments.

Formerly frogs, toads, and salamanders were placed in the class Reptilia, constituting an order. They have been separated, and now form a class denominated *Amphibia*. Their naked skins, and their metamorphoses, entitle them to the position they now occupy in our systems. They are inferior in rank to reptiles, and are more closely allied to fishes.

But, to be more particular, Order may be illustrated, 1. by reference to the class of birds. Some of the details which express ordinal characters will be found in the variable forms of mandibles and the locomotive organs—the legs and feet. Thus the birds of prey, the *Raptores*, have sharp hooked bills, and feet with sharp claws for seizing and holding their prey, as in fig. 12 and 13. The order *Scansores*, or climbers, have straight and somewhat wedge-form bills of great strength, and feet with four toes; two before and two behind, which fit them for climbing, as in figs. 15 and 16.

Fig. 15.

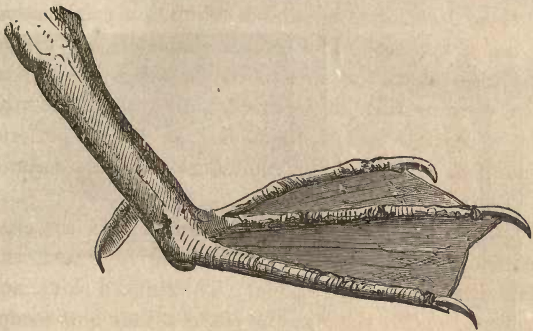
Bill of the Woodpecker.

Fig. 16.

Foot of the Woodpecker.

The order *Natatores*, or swimmers, have feet wholly or part webbed, as fig. 17. Another order, the *Grallatores*, have long naked legs, fitted for wading, as the *Herons*. They have long sharp triangular bills for seizing fish; others have slender bills for exploring the mud for worms, as in the *Snipe*, fig. 18. The foregoing embrace some of the details relative to some of the orders in the class Aves. These may be said to

Fig. 17.



Foot of the Duck.

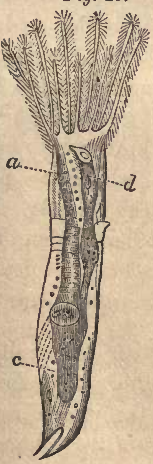
Fig. 18.

Snipe.

include the most important details belonging to the class.

Mollusks are divided first into *Mollusks proper*, as snails, clams, oysters, &c., and *Bryozoa*; the latter of which furnish certain general resemblances to the radiata, as in fig. 19. But their digestive organs are molluscan, their orifices for the reception of food and the discharge of excrements are distinct, as at *d; a* being the œsophagus, and their minute cells are not *septate*, as in the polypes. The first and highest order of mollusks are the *Cephalopods*, as represented in fig. 20. Their feet or arms surround the head and are provided with suckers. The *Gasteropods* move upon a broad foot, placed usually beneath, as fig. 3. The Pteropods have their organs of locomotion wing-like and placed upon the sides of their heads, as fig. 21. The Tunicata are soft animals, or without

Fig. 19.



Bryozoon.
Bowerbankia.

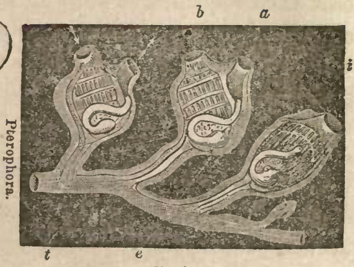
Fig. 20.

Cephalopod.
Octopus hawaiensis.

Fig. 21.

Pteropod.
Creseis subulata.

Fig. 22.



Tunicata.

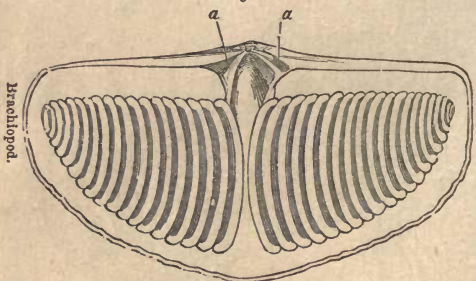
hard parts, and often live in families. They are enclosed in a sac, and have never been found in a fossilized state, Fig. 22. The arrows represent the course of the food.

The *Brachiopods,* or Pallio-

Fig. 23.

Lingula anatina.

Fig. 24.



Spirifer striatus.

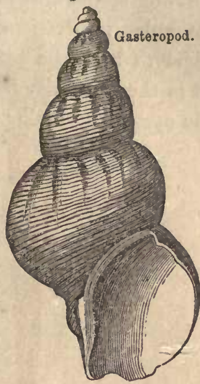
Fig. 25

Atrypa reticularis.

branchiata, are equally distinct, as an order, from the preceding. They are inequivalve bivalves; a large valve being applied over the abdomen and a small one to the back; and hence are distinguished as ventral and dorsal valves. The former has often a perforated

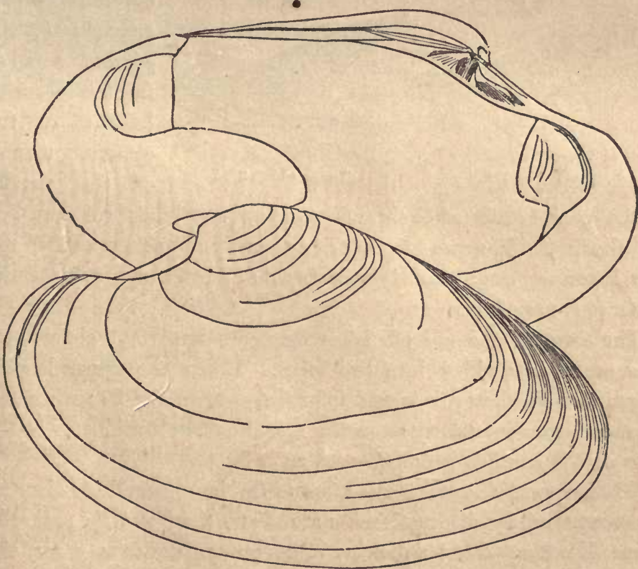
beak from which issued a byssus by which the animal attached itself to some foreign body: fig. 23 shows the attachment of the Lingula, a genus of this order. The mollusks of this order were also supplied with an internal calcareous skeleton in the form of *coils*, *loups*, &c., as represented by fig. 24, showing the spiral of the genus Spirifer (Spirifer striatus), and fig. 25, the spiral cones of the Atrypa reticularis. Some of the genera of this order were free: that is, they were not attached to a foreign body. The Brachiopoda are the most ancient mollusks known; they began their existence in the oldest sediments, and have continued down to the present epoch.

Fig. 26.



Tritonium Anglicum.

Fig. 27.

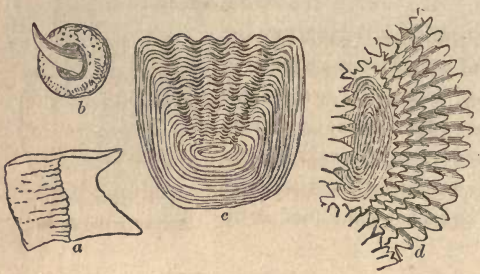


Cytherea.
Acephala.

We should not pass over the common divisions of mollusks into univalves and bivalves, or with shells consisting of one and two valves (fig. 26 and 27), the Cytherea, fig. 27, with its palleal line

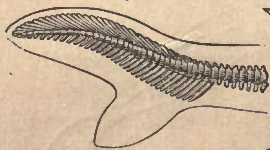
forming a sinus, as in the upper valve, upon the left, and its two muscular impressions placed at the extremes of the line. Other bivalves have the palleal line continuous and without a sinus; and as to the muscular impressions, many have one only, as it is seen in the oyster and scallop.

Fig. 28.



Scales of Fishes.

Fig. 29.



Heterocercal Tail.

Fig. 30.

Homocercal Tail.

The fish were divided by Agassiz into four orders, being governed by the form, structure, and composition of the scale. Fig. 28, *a*, the *ganoid* scale, of a rhombic form, and covered with enamel; *b*, the *placoid* scale, furnished with hooks; *c*, the *ctenoid* scale of the perch; *d*, the *cycloid* scale of the shad; the two last kinds are corneous and flexible. The two former belong mostly to ancient fishes; the two latter are comparatively modern, and did not appear until the cretaceous period.

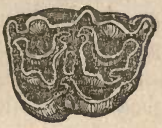
The form of the tail of fishes furnishes important characters. The organ is divided into two lobes. When the upper lobe is larger than the lower, it is said to be *heterocercal*, fig. 29: when the lobes are equal, or nearly so, or the spinal column terminates at the base of the lobes, it is *homocercal*, as in fig. 30.

23. In proceeding from the more to the less general divisions, it is maintained by distinguished naturalists, that, *family* naturally succeeds order; that families are often groups under an order, circumscribed by characteristics more or less well defined. Agassiz confines, however, family characteristics to form, not simply shape, but form, growing out of structural peculiarities; still, the meaning is closely allied to shape, which is due to the proportion of parts; or it may be expressed by saying, that it is due to the relative developments of parts, as to size and position, and hence, the

Fig. 31.

Cervus.

Fig. 32.



Bos.

Herbivora.

Fig. 33.

Insectivora.

Dromatherium.

characteristic is one of *likeness* dependent on form and proportion of parts. As such characteristics strike one at the first glance, it is evidently an outward character, and distinguishable without the necessity of dissection. For example, the bodies of groups of turtles may be comparatively high and oval, or round—or they may be depressed and circular—each form would constitute, if the principles have been stated aright, *families,* under the order Testudinata.

The families, however, as constituted under Mollusca by the most popular writers, do not seem to be founded on the principle of form alone; and we may remark, that it is impossible now to restrict this characteristic to family—botanists use it so constantly in specific descriptions, as, form of a leaf, seed, or root, &c., that it can scarcely be dispensed with. There are embryonic forms, and generic and specific forms; as well as forms which are peculiar to varieties. If the word *form,* is restricted by qualifications, its use will not lead to confusion in description. But if we substitute *likeness* for form, or relative proportion and position of organs, our error will be but trifling; for it is *likeness* which we seize upon at our first glance, and not form.

24. Families and sometimes orders, without family division, are divided into Genera. A genus finds its characteristics in what Agassiz has termed *complication of structure.* To us the expression is obscure, but by reference first to several genera we may catch a glimpse of his meaning. In the class mammals we find the orders *Carnivora* and *Herbivora:* the first flesh (fig. 5), and the last (figs. 31 and 32), herb eaters; and hence their feeding is very diverse, and their masticating and digestive apparatus are necessarily dissimilar. But carnivora differ among themselves in certain organs. There are the genera, Felis, and Canis; the cat and dog both are flesh feeders, and both have teeth adapted to the purpose; but their number and characteristics differ. In flesh feeders the crown terminates in cutting edges, as in the tiger. Their eyes and feet

differ, which differences become fitted to their habits. One is nocturnal, the other not. One watches for its prey and seizes it with a bound; the other openly pursues until it is overtaken. Their class characters are the same: they are mammals. Their ordinal characters are alike: they feed upon flesh; but then the number of their teeth, together with their forms, differ; the nails of their toes differ: in one they are retractile and kept sharp for tearing their prey. They differ in their whole economy, and these differences grow out of peculiarities of structure; and these peculiarities are generic characters, or complications of structure, as called by Agassiz. The cat is a higher grade of carnivora than the dog. To make out a cat, we examine its eye, its form of head, which is in part due to large muscles, its teeth, its feet and claws, its shoulders, and those characteristics which grow out of the peculiarities of these organs, and we have the *cat*, or genus *felis*, any cat, but not a particular cat, as the cougar, lion, tiger, and domestic cat. The same may be said of Canis or Ursus, or the plantigrade animals. We find characters which circumscribe groups; not individuals, but much more than individuals. The *Insectivora* are closely allied to the carnivora. Their molars bristle with points, as in fig. 33. The Rodentia have two cutting teeth in front in each jaw, as the beaver, squirrel, and hare.

25. The last and principal division which succeeds genus is Species. It is defined abstractly by the late Prof. Morton to be a *Primordial Organic Form.* If the beings to which species have reference are taken into view, it may be defined, a "group of *identical individuals, each of which is the representative of the species.*" Morton's definition is open to the objection that, in certain questionable cases, it is impossible to determine whether the form is primordial, or not. As it regards the latter, it is not agreed, and probably never will be, what differences in character are admissible without destroying the idea of identity. Those differences which are due to food, climate, or which are developed under new circumstances, do not destroy identity even though they become hereditary. That differences do spring out of a combination of circumstances and are transmitted to offspring, is admitted by all observers. But questions have arisen with respect to differences in beings which were acquired before the historical period, if acquired at all, and hence questions arise respecting their identity. One class maintaining that these differences are those which are *primordial,*

or conferred upon them when created. Others maintain, on the contrary, that such differences have originated in the stock posterior to their creation, from a combination of circumstances, and are of such a nature as to become transmissible to their offspring. This view is maintained by facts of a similar kind, and on the ground that changes have taken place within the historical period equally remarkable.

But the nature of a species, or the question what a species is, has been presented from another point of view, the *potential point*, as expressed by Dana, who in a communication to the Scientific Association, at its meeting at Montreal in 1857, maintains that species is essentially represented *by force.* Thus, in inorganic nature, hydrogen, an element, is represented by one, and oxygen by eight, and in all combinations of oxygen this number represents the species oxygen; or, in case of combination of oxygen with hydrogen, the result, water, will be $8+1=9$, which last number is the resultant of the force of affinity. So also it is maintained, on the same ground, that force is at the foundation of the idea of species in the organic kingdom. The force, for example, of the germ-cell, developes the being with its organs successively; or evolves by its force a new individual, that force operating as definitely and certainly in each branch, class, order, genus, and species, as in the inorganic kingdom, where we can express the force arithmetically; and hence, in both kingdoms, the idea of species is based on "*a specific amount of concentered force defined in the act or law of creation.*" A question may arise here, whether the idea of species, as maintained by Dana, is not something back of or behind the true one; for instance, whether in the case of water, the true idea of the species, *water*, is not to be taken from *water itself*, rather than from $8+1$; and so of organic beings, whether the resultant of the force of the germ-cell which evolves the new individual is not *the species*, rather than the evolving force or power which certainly lies back and behind the individual evolved. At any rate, there is a distinction between the evolving force and the resultant of that force; and, practically, *the resultant* is the object which furnishes the phenomena by which species are defined and circumscribed.

A definition of a species belonging to the organic kingdoms cannot be fully expressed in a few diagnostic characters; inasmuch as it involves genealogical descent and perpetual fertility; certain relations as to time and space, to duration and place, mental organi-

zation and unity of thought, food, habits, shape of organs, color and ornament. Where identity extends to, or includes all of these points, and we find them common to a group of individuals, we may pronounce those individuals one species.

A species never changes into another species, for a very good reason; it is derived from the germ-cell of parents, and hence is endowed with a *parental force.* In order to effect a transformation of a species, it would require (if the expression is allowable) a new creation, or a new endowment unknown to the species, or, in other words, *species* in all cases are continued developments of germs, endowed with a specific force; and hence a germ cell has no other force than that derived from the parent, or what it has received. Specific force is a *constant* in nature, imparted to a cell by previously existing beings; and hence it is unnecessary to go into detailed historical observations, since we know that no organism is ever developed independently of a *cell,* and which is universally the product of parentage; both history and physiology support each other upon this question.

26. *Varieties* originate in the individuals of a species, endowed with limited differences from the common type, which become permanent. The most striking varieties have sprung up under the influence of domestication, though in the vegetable kingdom they have been observed outside of man's influence, but not necessarily multiplied, or extending beyond the individual. The seed of varieties rarely reproduce the variety; it requires the cellular tissue as cuttings to effect a continuance of the variety; though in the cereals the varieties are propagated by the sexual organs. In the apple, pear, &c., it is the identical cellular tissue which is reproduced in the fruit by cuttings or buds, which is a part of the organization which is uninfluenced by the pollen.

27. Identity of character involves resemblance or likeness; as the word resemblance is generally used, it lies at the foundation of classification; for in every division it will be noted, that there are certain common resemblances existing in order to make out the large or minor divisions of a kingdom.

There are, however, resemblances of two kinds; one, which is *proximate,* and which belongs to individuals of one stock, or which is *genealogical;* and another which is *remote,* and is really only *typical;* it belongs to the type. In the first the resemblance is one of relationship, in kindred; in the other it is simply typical

or of an *approximate kind*, there is no relationship. Specific character, it will be perceived, takes in a wide range of expression; and there remains still one field of research for the exhibition of specific character, which is often of the utmost importance. It is the development of the embryo. The evolutions of the embryo in the same species are identical in all respects; the force of the germ-cell evolves *by law*, and the respective changes indicate as certainly as possible the species; for the changes or evolutions of the embryo have, at every stage, reference to species, not class, order, genus, but entirely to species. Hence we may employ embryonic changes as indicative of species; or we may employ the resultant of embryonic forces as indicative of species. If, however, every stage in the evolution of the embryo points to the species, the resultant is not only representative, but is the species itself, and should be invested with specific attributes and characters. It is representative so far as class, order, and genus are concerned, but it is also in itself species, and any individual is invested with a representative character, which extends upwards through all stages of life, the specific, generic, and ordinal, ending in the branch to which it belongs. It has no relations except those of the highest kinds to the branches from which it is excluded on the ground of difference of plan of organization.

A Synopsis of Classes and Orders belonging to the Animal Kingdom.

The Mammals are divided into two sub-classes: the Monodelphic Mammifers and the Didelphic Mammifers. The first contains twelve orders.

I. SUB-CLASS—MONODELPHIC MAMMIFERS.

1. The Quadrumana, or monkeys.
2. The Cheiroptera, or bats.
3. The Insectivora, insect eaters.
4. The Carnivora, flesh feeders.
5. The Rodents—rat beaver.
6. The Edentata, no incisive teeth.
7. Proboscideans—elephants and mastodons.
8. The Pachyderms—pig, hippopotamus.
9. Ruminants—ox, deer.
10. Sirenoides, pisciform, and destitute of posterior members—dugong.
11. Zeuglodon, only known in the fossil state; pisciform, teeth numerous; molars trenchant and denticulated.
12. Cetaceans, teeth conical or none, pisciform, destitute of posterior members—whales, &c.

II. SUB-CLASS—DIDELPHIC MAMMIFERS.

1. Marsupials, flesh feeders; young, occupying an exterior pouch at an early day—opossum and kangaroo.

2. Marsupials, vegetable feeders.

3. Monotremata; supplied with a corneous beak, or mandible, one opening for the alimentary canal and urinary and genital organs, teeth none or abnormal.

A Synopsis of the Class Reptilia.—6 Orders.

1. Testudinata, or turtles.

2. Sauria, contains three families: 1. Dinosaurs; long bones partially hollow like the mammals, and with a sacrum composed of 5 bones—iguanodon, &c. 2. Crocodilians. 3. Lacertians.

3. Pterodactyles, flying lizards.

4. Enaliosaurs, marine lizards, furnished with paddles—ichthyosaurus, &c.

5. Labyrinthodonts, teeth remarkable for their complex structure. The skull has the double condyle of the batrachian.

6. Ophidians, or serpents.

Class Amphibia.—3 Orders.

1. Batrachia anoura, or frogs, destitute of a tail in the adult state, skin naked.

2. Batrachia urodeles, tail in the adult state, as in the salamanders.

3. Cecilia, serpentine form, and destitute of external limbs, unknown in the fossil state.

Classification of Fish after Pictet.

He admits the following orders arranged under two sub-classes.

I. SUB-CLASS—TELEOSTEANS.

1. Ctenoid, scales of ctenoid type.

2. Pleuronectes, head unsymmetrical, scales of the ctenoid type—flat fishes, as the flounder.

3. Cycloides, acanthopterigian; scales rounded, smooth, and sometimes sinuate, anterior dorsal rays spinous.

4. Cycloides malacopterigian, dorsal rays soft.

5. Siluroids, soft rayed and abdominal, without scales, skin naked or cuirassed—cat-fish.

6. Plectognathes, skin hard or plated—balistes, diodon.

7. Lophobranches, body cuirassed, branchia in tufts, rounded, disposed in pairs—sygnathus.

II. SUB-CLASS—GANOIDES.

1. Ganoides cycloferes; it contains four families: amides, leptolepides, celacanthes, and holoptichides.

2. Ganoides rhombiferes, scales rhombic. 3. Holopleurides, skeleton bony, body furnished with plates disposed along the back and flanks. 4. Ganoides cuirasses, skeleton cartilaginous, without scales covered often with bony plates; it contains three families: 1. Cephalaspides. 2. Sturiones or sturgeons. 3. Spatularides, body naked. This sub-class evidently contains a heterogeneous assemblage of fishes.

CHAPTER III.

CLASSIFICATION CONTINUED.—VEGETABLE AND MINERAL KINGDOMS.

28. THE vegetable kingdom seems to have been created upon two plans, or to be evolved in two distinct branches. The first, the *seed*-bearing plants, and the second the *spore*-bearing plants.

29. The seed-bearing branch may be divided into *Polycotyledons, Monocotyledons,* and *Dicotyledons,* which are regarded as classes.

The spore-bearing are divided into *Thallogens* and *Acrogens,* which appear also to be entitled to the rank of classes. The *Polycotyledons* contain the coniferæ, or class of pines. The *Monocotyledons,* the cycads. The *Dicotyledons,* when trees are considered, form a class to which all our fruit trees belong, and also a large proportion of the forest trees and shrubs, of course excluding the pines.

30. The *Thallogens* include marine plants, which are generally known as *sea weeds;* the *fungi* or toadstools, as they are familiarly called; and the *lichens,* or leathery foliaceous plants, which grow on rocks, trunks of trees, fences, &c.

31. The *Acrogens* comprehend the mosses proper, the ground-pines, or club-mosses, and sometimes called Lycopodites, and the ferns. The two former have small veinless leaves, the latter have veins which are forked.

32. Seed-bearing plants may be viewed from another point: first, as to the growth of the stem. In this feature they present two kinds of growth. 1. Those which form annually a layer of wood upon the outside. They are the *Exogens,* or outside growers, as the maple and apple. 2. Those which grow from the inside, or *Endogens,* as palms, Indian corn, &c. We may also notice their leaves, particularly with respect to the distribution of veins. The dicotyledonous plants, or exogens, exhibit veins which branch in various ways, or they are said to be *reticulated.* The endogens, or monocotyledonous plants, have parallel veins. From these com-

mon characteristics the student is furnished with a clue to the class to which a plant belongs, if he has a seed, a leaf, or a fragment of a stem. The spore-bearing plants have exclusively a cellular structure, except the ferns, which have spiral vessels; in consequence of which, as a great division, they have been called *Cellulares*, in contradistinction to *Vasculares*, which are furnished with spiral vessels.*

We do not propose to proceed farther with the classification of plants, however interesting the natural and systematic arrangement may be. It would occupy too much space for the objects of this work. We shall have occasion to refer frequently to the foregoing general divisions, partly for the purpose of showing that they have appeared upon the earth in a certain period, or that each class belongs to different periods of the earth's history.

33. The class minerals, which in its meaning is co-extensive with kingdom, may be divided into orders, and these orders again into genera, and finally into species. That there are large groups of minerals which possess properties in degree and kind within certain limits is no doubt true, and these groups, while they possess them in degrees in kind and quality, also look alike; that is, we cannot fail to perceive there exists an outside likeness; we say *outside*, for in classifying minerals no regard is paid to chemical composition; indeed, not only are the characters outside characters, but the force which brought their elements together are outside forces also. Class, in mineralogy, then, circumscribes or comprehends all inorganic bodies, oxygen, water, iron, mercury, quartz, mica, &c. They are characterized by the absence of organs. Order circumscribes a group of genera under one or more common characters. Thus the order *Mica* includes those which are remarkable for their easy cleavage in one direction.

34. The order *Gem* includes those which have a remarkable degree of hardness; the degrees of which are limited between 7 and 10; lustre semi-metallic, specific gravity, between 2.8 to 4.6. The order Baryta, by hardness between 3.5 and 3.8, and gravity between 3.3 and 6.5. This order embraces soft minerals, but their specific gra-

* The division of stems into endogens and exogens is now regarded as of less importance than formerly, as it is maintained that the actual mode of growth is much the same in both divisions; still, as the structure of these stems are really distinguishable, and as they actually embrace plants which differ in other respects, it seems to be important to the geologist to keep up the distinction.

vity is high for earthy bodies; lustre adamantine, in different degrees. Carbonate and sulphate of lead, carbonate and sulphates of barytes, &c., are examples. Properly, an order (omitting genus) is represented by a series of species, and their characters, though of the same kind, are strictly definite; each species has its own degree of hardness,* its own specific gravity, its mathematical form and fixed dimensions, its color and its optical relations.

35. The classification of inorganic bodies or minerals is based on principles quite different from those which we have just considered. We retain, however, as far as possible the same names for the divisions, as class, family, order, genus, and species—that is, there is no objection to the use of these names provided there are divisions which answer to them.

We also recognise the same principle as the basis of classification, viz., *resemblance.* The resemblance, however, is of a different kind from that which is recognised in the animal and vegetable kingdoms. In minerals it is *physical,* and we may remark here that there is no affinity or relationship existing among inorganic bodies. Classification is founded on the resemblance of physical properties, as weight or specific gravity, hardness, form, color, lustre. Where a group of bodies possess the same gravity, the same hardness, form, color, and lustre, they are regarded as identical, and constitute but one species.

36. In the mineral kingdom bodies exist as *elements,* which are undecomposed kinds of matter, and as *compounds,* which consist of the union of two or more elements, forming thereby a homogeneous mass. When, however, such bodies are aggregated together, they are called *mixed* minerals, as quartz, felspar, and mica, in granite.

37. The term *simple* is used in mineralogy in a sense differing from that in which it is employed to express composition; *simple,* in mineralogy, is really *homogeneity;* that is, to the eye the mass forms only one kind of matter; it appears to be simple, but still is composed of two or more elements, as carbonate of lime, felspar, garnet, &c.

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* The degrees of hardness are expressed by a scale, divided into ten parts, beginning with the softest mineral (talc) known, which is represented by hardness = 1: and ending with the hardest, the diamond with a hardness = 10. The ten selected minerals representing hardness are talc, salt, calcspar, fluorspar phosphate of lime, felspar, quartz, topaz, sapphire, and diamond.

Another distinction should be stated. Minerals occur under regular geometric forms, or they are amorphous. The former are crystals, bounded by regular planes, terminating in edges and angles. These planes and angles bear certain relation to imaginary lines passing through the crystal in the centre of faces, edges, or angles, and which are called *axes*. Amorphous minerals have no forms which can be referred to a geometric solid. Neither do they break in a manner which indicates a regular arrangement of their particles. In many amorphous masses, however, a crystalline tendency is often observable, which shows the existence of law, and that inorganic matter, if left to the influence of its own primordial force, would take or assume regular forms.

In classification of the bodies belonging to the mineral kingdom, we can find no great division corresponding to branch in the organic kingdoms. Indeed, there is strictly but one class. We may divide minerals artificially into classes, but they are unnatural, as those of Mohs's three classes.

38. Though we admit that order is exhibited in the foregoing classification, yet we are unable to discover in this class of bodies either a *typical* or *genetic* relationship. This being admitted, it is evident that the systematic arrangement of orders and species is effected on principles of another sort. If we now subject this classification to a rigid examination, we shall be able to discover that species have *position* only in virtue of their external aspects and characters; it is not *relationship* or *affinity* which gives them a collocation in the system; for example, quartz, topaz, emerald, zircon, and beryl are placed in the order Gem, for the reason that there is a *physical resemblance* among them which we cannot disregard in classification; but it only gives the several species of the order a *standing* there, because they possess a certain degree of hardness, a certain kind of lustre, and a certain amount of gravity. To these physical properties their *position* in the group is due, and not to *relationship* of any kind. A classification which expresses *position only*, and not the higher genetic and typical relations which exist in the organic kingdoms, is a classification of an inferior kind. It is a classification, however, because it is founded upon permanent characters and fixed relations. This is the only classification, too, in which it is possible to arrange bodies in a linear series. Minerals, in this respect, show their *simplicity* in contra-

distinction to the *complexities of structure* both in the animal and vegetable kingdoms.

In conclusion, we remark that we often find it necessary to test the value of the abstract principles by which we have obtained certain results, as the systems of classification which we present above, or, in other words, we wish to be satisfied that we have seized the governing characteristics of a plan or scheme. We may be satisfied with results when we find that thoughtful men have bestowed proper attention to characteristics, and they obtain the same results, though they have pursued different ways. Again, if a scheme of classification is applicable to the *past* as well as the *present*, the scheme is worthy of confidence, or merits belief. If, again, a scheme is tested by two or more methods, and they agree or harmonize, then we may regard the groups as natural, and that the ruling characteristics have been selected aright, and the scheme is founded upon those general principles which a truthful representation requires.

Fig. 34.

Euripterus remipes. Upper Silurian.

CHAPTER IV.

GEOLOGY DEFINED—ITS OBJECTS, ADVANTAGES—MEANS BY WHICH IT IS ACQUIRED, AND THE RULES BY WHICH ITS PHENOMENA ARE INTERPRETED—SOURCES OF INFORMATION POINTED OUT—IMPORTANCE OF THE TESTIMONY OF ORGANIC REMAINS—GEOLOGY BASED ON AUTHENTIC RECORDS—THE THREE PERIODS—ORIGIN OF WATER, AND CONTINENTAL RIVERS AND SEAS.

39. GEOLOGY is a natural history of the earth. It treats of natural bodies, forces, and succession of events. A relation of those events, arranged in the order in which they happened, would form a complete history of the planet since its creation.

40. Some of the objects of Geology are, to acquire a knowledge of the earth's structure, to discover the causes which produce many of the phenomena that so frequently arrest our attention—as earthquakes, volcanic action; also, those which have been instrumental in the accumulation of the metals near the surface; together with those which grow out of the relation of the component masses, and their mutual action upon each other.

41. The advantages which flow from its study are numerous. It informs us where we may expect to find many of the valuable productions in the earth—as iron, copper, gold, silver, mercury, salt, gypsum, coal, and marble; it gives us enlarged views of the Creator and his works, by which we also acquire rational views of the plan of creation.

42. It gratifies a laudable curiosity in reference to the past, by giving us a more correct knowledge of what transpired in the earliest periods of the earth's existence. It shows, from abundant data, that the earth passed through many important changes prior to the creation of man; that plants grew, and animals lived, upon the earth long before his existence; and also, that the changes and revolutions upon it were necessary to prepare it for his abode, and that those changes indicate progressive states; that order has prevailed; and that with respect to plants and animals, that they

appeared in the order of their rank; that those especially which are low in the scale of organization belonged to the ancient periods, while those which hold the highest rank were created in later periods, and just before the creation of man.

43. The means by which geology is cultivated, or a natural history of the earth is acquired, is by observation and the application of the established principles of chemistry, mineralogy, botany, zoology, and natural philosophy. Under the guidance of the principles established in these departments, the geologist proceeds to examine the relation of rocks to each other, to ascertain by what agencies they have been formed, whether they have been moved from the position they originally occupied, and also what they contain. The geologist often finds it necessary to descend into mines, ascend mountains, trace out rocks along watercourses or railroad cuttings, or visit any natural or artificial exposure, to which access can be gained.

The kind of observations which are to be made depends upon the object which we have in view. It may be to determine the order in which rocks are superimposed upon one another; or it may be to discover the existence of the valuable metals, ores, coal, marble, salt, &c.

These questions, however, are too numerous to be elaborated in an elementary treatise.

44. The interpretation of observations which are thus made, must be in accordance with established principles, as we have already remarked. For we may safely assume that, in all time, all changes and all phenomena have been produced by causes now in operation. They may now operate with less activity, but they are the same in kind; so that we may safely apply the established principles of modern science to the explanation of those ancient changes, and have no occasion to infer that because an event is remote in time, it was the result of causes unknown in our time. The present furnishes us with all the information required to make a correct interpretation. Fire, water, and atmospheric influences, &c., have been the same throughout all time; the same laws have governed their effects; water was converted into steam, cold condensed vapor, fire melted rocks, and the expansion of steam and aeriform bodies rent asunder the strongest walls in remote times, for the same reasons and under the same circumstances as they now do.

45. Our most authentic information respecting the earth is derived from records which may be said to be inscribed upon and within its strata. These records consist of two kinds, the physical and organic. To the first belong the changes produced by the action of one portion of the earth's crust upon others, which may be seen where its strata are bent, or crushed, or moved from their former positions; and also the intrusions of rocks in a melted state among those already consolidated, so that the latter are baked and otherwise changed by the intruded molten mass.

To the second belong the remains of animals and plants, which were enclosed in the strata and have been preserved in states sufficiently perfect in most instances for the recognition of the families to which they belong, and in other cases for the exact determination of the species.

46. The testimony of the remains of plants and animals is of the utmost importance. They not only inform us of the general order which we have already mentioned, but especially when the representatives of the different kinds first began to exist, as birds and mammals; also when particular species ceased to exist, and new representatives took their places. From their distributions and the peculiarity of their organization, we infer the former condition and temperature of the earth.

These organic records fully bear out the conclusion, that the plan of organization of the remotest periods differs in no respect from that which now prevails, and there is no deviation in structure from the four Cuvierian types known to us under the names of Radiata, Mollusca, Articulata, and Vertebrata.

47. From the foregoing statements it will be perceived that geology is based on authentic records. It has established the law of uniformity of action in the physical world, and a uniformity in the organization in the organic kingdoms, which furnishes a basis for the interpretation of both classes of phenomena, and assures us of the safety and soundness of applying the same rules of reasoning to the remote ages as to those in which we live.

48. In the preceding paragraph, reference has been made to remote periods. The most general division which can be instituted, with respect to our knowledge of these periods, is that of the three following, which may be entitled the *hypothetical*, the *theoretical*, and the *positive*. The *theoretical* may become positive when its theories are so fully established as to be universally received as true

by those capable of weighing the proof. The *hypothetical* is the most remote, and goes back to a time when the matter which now composes the earth, the sun, and the planets, is supposed to have existed in what astronomers term *a nebulous state*, a state of extreme diffusion through an almost illimitable space. That matter did so exist, the proof is by no means direct. It is an assumption, and therefore properly called an hypothetical state.

The theoretical period presents certain tangible facts, as the form of the earth (an oblate spheroid), and the composition and physical characters of its masses; from which we may reasonably draw conclusions.

The matter composing the earth has now become consolidated, and during consolidation chemical agencies have been active among its elements, intensely igniting its mass, and giving it a state of fluidity sufficient to cause its matter to accumulate upon its equatorial parts by rotation. They also gave sufficient fluidity to permit its particles to move freely among themselves, from which has resulted the crystalline state of its oldest rocks.

49. The third or positive period, finds the earth in a comparatively settled condition; its surface has cooled, and its fires, which had been lighted by the powerful affinities of matter, have, as it were, burnt out, and they exist only in its interior; vapor condenses upon its surface, and as the forces which have been generated by its ignition, have broken and ridged its outer envelope into mountains, the condensed water flows in streams and rivers from the slopes towards the great depressions to which all converge, and where all the waters of a continent unite and form the great reservoirs which are known as seas and oceans.

50. The origin of water upon the earth, as thus explained, seems to assure us that it was the last element contributed to its surface from the surrounding space, that its accession added an important force antagonistic to that of fire, and that it has essentially modified its surface by its mechanical and chemical properties; in fine, has been the principal agent in rendering it inhabitable by beings organized like man, and the lower animals.

51. It may also be inferred that, as seas must have been formed by continental rivers and their contents have accumulated gradually, so their saline matter must have increased slowly: hence, in the early existence of the planet, the oceans were less saline than now—an assumption which seems to be sustained by the absence of salt in the oldest sediments, though they are all marine.

CHAPTER V.

OF GEOLOGIC FORCES—FIRE AND WATER CONSIDERED AS AGENTS OF CHANGE—DYNAMICS AND STATICS OF GEOLOGY.

52. THE forces which have been instrumental in giving form to the earth, as well as in arranging its subordinate parts, are two—*Chemical* and *Mechanical*. And the agents immediately concerned are also two—*fire* and *water*. These are, however, generally spoken of as the *forces* of geology. The changes due to each are sometimes chemical and sometimes mechanical. The first force brought into activity was fire. It was generated or first kindled by intense chemical action of the elements upon each other, when their atoms were brought together by condensation from that highly diffused state which we have referred to in the preceding chapter. The questions which relate to this nebulous state of matter, or hypothetical period, belong to astronomy. The geologist, however, has occasion to refer to it for the purpose of indicating the origin of those fires whose former existence seem to be established by the peculiar form which the globe has taken—the crystalline state of all the inner deep-seated masses, and by the actual existence of fires within its crust at the present time. This present heat of the earth, we thus endeavor to trace back to its original cause; a cause certainly adequate—regarding it as the *residual* heat of the cooling globe, and not transient heat developed at uncertain intervals by the chemical, or galvanic action of the materials upon each other. Though these forces undoubtedly still perform important parts, they are at present rather the results of this heat than its sources.

53. In connection with the heated state of the earth, it is necessary also to consider it as a cooling body—as constantly losing its temperature by the escape of its caloric into space. An envelope or crust consequently first formed, which has thickened by the loss of heat. This thickening of the first pellicle formed must be beneath, so that the crystalline covering of the earth

is a *nether* formed crust; the newest portion being nearest the centre of the globe.

54. In considering the time required to form a cool and stable surface, we must take into account the relation of the rocks to heat, considering them as good or bad conductors, and also the fusibility of different materials of which they are composed.

55. In the combined effects of heat, and of its escape, the geologist recognises causes which are competent to elevate above the general level of the surface, portions of the earth's crust. And probably in ancient as in modern periods, these portions were raised in ridges, or formed chains of mountains similar to the Alleghanies, Alps, or Andes.

56. The effects of the fire force are also seen in the fusion and heating of strata wherever exposed to its action. It thus vaporizes water, disengages the gases from their compounds, and even vaporizes sulphurets, phosphates, and other bodies that have metallic bases.

57. Vapors and gases being generated, they must either escape through fissures, or, being confined in cavities, they exert great pressure upon parts already fluid, or upon the solid crust. Pressure upon an incandescent fluid may force it through cracks and fissures, and on reaching the surface may flow over it and cover strata already consolidated; instances of which are often witnessed in our day in the overflowing lava. The confined vapors may also force upward the crust, cause earthquakes, and permanently elevate that portion immediately above the place where they are confined. But it is maintained that mountain ridges are rather due to subsidence of the strata, by which the outcropping edge is tilted up, thus forming a ridge. The instances of change of level, however, in our times are accompanied by increased activity of the fire force, so that this agent is probably always concerned in the formation of single mountains, if not all mountain chains. Thus the Alla Bund, or Mound of God, in India, was raised during an earthquake, in 1819, ten feet high, sixteen miles in width, and fifty miles in length.

58. We trace, also, the origin of veins and dykes to igneous action. The rocks being rent asunder by the cooling of the strata, or upward pressure of the gases, a passage is opened for the water (from above), holding in solution various substances which may be deposited upon the walls of the fissures; or for the gases

and vapors from beneath, consisting of the sulphurets and chlorides of the metals, or disengaged sulphur. The known laws of condensation of such bodies upon a cooled surface, would satisfactorily account for the filling of those rents with the metals and their compounds. The fissures called dykes were filled with melted matter forced up from below. Though the common effect of fire is to elevate the surface and force up melted matter, it sometimes undermines large areas and causes a subsidence.

59. The force of water is scarcely less important than fire in modifying the surface of the earth. It operates in four modes, viz.: by solution, by its expansion in freezing, by attrition, and by transportation. As a solvent, under common circumstances, it is not necessary to speak of it particularly. When it is aided by heat or pressure, it is much more important. If aided by heat and pressure together, it dissolves silica and many other substances, as is shown by the Geysers of Iceland and the waters of other hot springs, which upon cooling let fall the matter that has been dissolved, so that in the course of time large accumulations form around the orifice where the waters issue. When it holds carbonic acid in solution, it dissolves carbonate of lime and iron, which it lets fall also when exposed to the atmosphere. The tufa about springs, and also porous oxide of iron, which are not uncommon deposits, are thus formed.

60. When water freezes it expands with great force. Rocks are thereby rent asunder by the ice formed in their seams; and all porous bodies, which absorb water abundantly and afterwards freeze, are broken up and reduced to soil. It is however much more important as a mechanical force, when acting as a transporting agent. As it flows in streams and rivers from the mountains to the oceans, the debris which is committed to it is carried along to these great basins. It is estimated that the Mississippi bears down sediment enough annually to form a stratum one foot thick and 12 miles square. The tide wave impinging upon shores, and flowing into harbors and up rivers, transports sediment during its ebb, and as it pursues outward its course, deposits it at all points where its force is diminished by obstructions. A bar is formed where it meets river currents, and hence the navigation of rivers is often obstructed. The Atlantic tidal wave is both constructive and destructive. It is more destructive when its force is aided by winds. The waves which break upon the shores cast up sand,

a part of which is often blown inland, making desert and sterile large areas which lie in the course of the prevailing wind. Another portion of the land is often raised into a ridge nearly parallel with the shore line. Such ridges often form along the shore of inland lakes, and have been mistaken for moraines.

61. The great ocean river, known as the Gulf Stream, is a still more important flow of water. It is a bearer of both heat and sediment.

That portion of the great equatorial current between Africa and America, impinges upon Cape St. Roque, in Brazil; then flows onward into the Mexican Gulf, where it is heated to 88° F.; then passing out by the Florida Keys, it flows N. E., and finally approximates the north-western coast of Europe. It parts with its heat, which is distributed by the prevailing westerly winds over the western and north-western coast of the Continent. During its progress the fine sediment it received from the Amazon and Mississippi, is distributed along its course upon the ocean's bottom.

62. The vastness of the scale upon which water operates, is indicated by the extent of ocean surface. Thus, the Atlantic has an area of 25,000,000 of miles; the Pacific 70,000,000; while the earth has only 35,000,000. Fig. 42.

63. From the foregoing statements, we may perceive that the sediments which are transported by water to the ocean are the materials of a large class of rocks, which it is evident may be recognised by the earthy character which they must assume, and the intermingling of such debris with various kinds of organic matter. Water in the act of transporting the debris of rocks, whether fine or coarse, must necessarily bring this matter into collision with rocks and with its own moving particles: hence, most matter thus transported bears evidence of the attrition to which it has been subjected; and the rocks bear external evidence of their origin, though the limestones, which seem to have been, in part at least, in chemical solution, are frequently crystalline, and in this condition their sedimentary character may be disguised. The winds are important agents in producing geological changes. Evaporation goes on continually. From oceans, seas, rivers, lakes, and the surface of the earth, vapors of water are ever rising, borne by winds over the highlands and mountains of continents; it is there condensed, and falls in the form of rain, or snow, affording a never-failing supply of water for mountain streams and continental

rivers, to flow on back to the oceans and large bodies of water, and to rise again in the form of vapor. Great changes are effected by this circulation and interchange. Slowly, but surely, the hardest rocks are worn down and softened; the surface of the whole earth is modified; debris from the mountains and hills is carried down and spread out over the plains, or the ocean beds.

64. We may observe in closing our remarks relative to geologic forces, that they are often alluded to as the *Dynamics of Geology*, a phrase which is employed to express in the aggregate all the forces which have been in any way productive of change in and upon the earth's crust, whether *fire* or *water*, *molecular force*, the *assorting power of water*, or *chemical action*.

65. The *Statics of Geology* is another phrase equally comprehensive. It is designed to express the condition of the rocks and of the surface *as they are*, without regard to *cause*. Statical geology, however, stands first in the order of investigation, or of time. It is necessary to observe and weigh all the facts respecting the *statics*, before we are in a condition to determine questions relative to their *dynamics*. The *dynamics* should always grow out of the *statics* of geology. When the statics have been fully investigated, the deductions of geology are placed upon as sound a basis as those which belong to astronomy. Or when our conclusions are thus guarded and eliminated of suspected error, the earth's history becomes as truthful and as worthy of belief as the history of the ancient nations, Greece and Rome.

Fig. 35.

Disintegration of granite, resulting in the form called tors or *cheese rings*.

CHAPTER VI.

CLASSIFICATION AND NOMENCLATURE OF ROCKS.

66. THE principle upon which a classification of rocks should be based is no doubt that which recognises in its scheme those facts which express the mutual relation of all the masses composing the earth's crust. This principle is probably the true one, because it expresses the historical idea, which in geology is always the prominent one, and the one which requires the fullest elucidation. This principle, however, has not been employed in classification excepting in a very general sense. In the older classifications attempts were made to sub-divide rocks upon this principle; thus, the threefold division into primary, secondary, and tertiary expresses this relation. A more recent threefold division is indicated by the use of terms which express remotely the sequence of formations according to the antiquity of their organic remains, and they are tolerably well expressed by the terms *Palæozoic*, *Mesozoic*, and *Cainozoic;* terms which have reference to the relative age of the fossils which are contained in the rocks.

While then, the classification of rocks is based upon the time or period when they were formed or deposited, the nomenclature is not fortunate, as there is generally a want of meaning in the names which correspond to the historical idea. The rocks, or groups of rocks, fall, it is true, into an historical arrangement, but the nomenclature fails to express it except in the most general way; and probably in the present state of the science it is not possible to change it materially, or even so far as to bring about a reconciliation of the historical arrangement with the names employed to express it. Hence it will be observed that certain names which are employed for the groups or systems, are derived from localities or places where the particular rocks, groups, or systems are supposed to be displayed to the best advantage for study. Thus the terms Silurian, Devonian, and Permian indicate localities. Other names express merely a

fact indicative of the lithological composition, as Quartz Rock, Calciferous Sandstone, Cretaceous System : or in other cases, the mineral contents, as Carboniferous: in others still, the names are derived from the structure of the masses, as Lias and Oolite: and lastly, names are employed which express the relations of past periods to the present: as Eocene, Miocene, and Pliocene. In this country it has been customary to adopt the European names of classes, and apply them to our larger divisions or their equivalents. Thus in New York, it turns out that the rocks which prevail over the greater part of the state may be referred to the systems which in England have been called Silurian and Devonian; accordingly, we speak of the Silurian and Devonian systems in this country in the same manner as geologists of England, though we have neither a Siluria nor a Devonshire. But while we thus adopt the general European names for our systems, we have applied American local ones to our groups or subordinate divisions. These names have been generally selected from the places where the groups may be studied to the best advantage; for example, the Potsdam sandstone, Champlain group or division, Onondaga limestone, Niagara group, &c., are names applied according to the principle stated. The term *series* is often employed in place of the word *group*. In either case the words indicate that there are several beds or rocks which are closely connected together, or so closely related by their fossils, that they belong to one epoch.

67. The most general divisions which are now adopted in this country are based upon the nature of the forces which have been instrumental in their formation. These divisions are recognisable by the phenomena peculiar to their operation and effects. Fire produces effects which need not be mistaken; variable it is true, according to conditions, but recognisable still, though extremely different. In one case fire gives us perfect crystals, or a crystalline mass, as in granite; but lava, which is a molten rock, is an amorphous slag or a glass, which being cooled suddenly in the air, its particles had no time to arrange themselves symmetrically; thus conditions determine the results.

Rocks which are crystalline by the influence of this agent are properly called *Pyro-crystalline;* crystallized by fire. It may be assumed that at one period the entire crust was acted upon by fire. Its exposure, however, in space to a cold medium, abstracted the heat, until, in process of time, it was reduced to that temperature

which was required to condense the surrounding vapors. The deposition of water was the result; and it speedily became itself an agent of great force and power. This agent became, too, the parent of a new class of rocks; these were formed mainly by its mechanical action, or by abrasion of the consolidated crust. From the nature of its action and the insolubility of the materials thus produced, their consolidation would result in the formation of amorphous beds, or strata, superimposed upon one another. The movement of the waters would mould these materials as they gradually accumulated, and hence this class of rocks has been appropriately named *hydroplastic*, *moulded by water*, or, in consequence of their being formed of particles deposited in this medium, they are frequently called *sediments*, or *sedimentary rocks*. But water under favorable conditions dissolves the materials which are in contact with it, and hence such rocks do not appear like the mechanical sediments; they are even crystallized: this is particularly the case with the limestones.

As the phenomena of fire are due to its variable action, according to the condition of the body when cooling, and the length of time its heat is escaping, it is necessary to recognise another class or division of rocks; those for example which are cooled under great pressure, having been ejected from fissures and flowed over masses already consolidated; and those masses which are ejected from a crater into the open air, all such rocks may be called *Igneous* or Pyro-plastic rocks. These are massive, though crystalline particles may be disseminated through them. They are found in thick beds reposing upon those which are sedimentary or pyro-crystalline, or they fill ancient rents, formed in consequence of the cooling of the earth's crust. The term *primary* has been very generally applied to the first of the foregoing divisions or classes; but as some of the pyro-crystalline rocks, as the granites, have been formed in all periods, the term is therefore loosely applied; indeed all the members which make up these divisions belong to all periods, and hence the names employed are general, and express merely the nature of the agent to which they are due.

68. The Hydro-plastic rocks, or those due to action of water, have been subdivided into three divisions. The names applied to these divisions express the relative antiquity of their organic remains, as the *Palæozoic*, the ancient forms of life; the *Mesozoic*, the middle forms, and the *Cainozoic*, the recent forms of life, or which most

resemble those belonging to our own period. The term *primary,* it should be observed, is sometimes applied to the palæozoic rocks; it then has reference to the organic beings which they enclose. They are primary, as they were created first, or have preceded many other organic beings in time.

69. The three foregoing divisions, however, are not of equal length. The oldest, or palæozoic, is by far the most protracted period, the cainozoic is comparatively short. The annexed diagram expresses the relative length of these periods

While, however, the inequality of these periods is a well established fact, there are reasons for their adoption. In the first, or cainozoic, the organic remains as a whole are closely related to those now living, and besides in the oldest beds a few species are identical with those which still exist.

On the contrary, there are no living species in the mesozoic period, and their general characteristics are more remote from those of the living, than those belonging to the first or foregoing division. The organic remains of the *palæozoic division* resemble still less the animals and plants with which we are familiar, and most of its genera are extinct; and hence is in reality the period of ancient life as its name expresses. The progress of discovery may change somewhat the relations of these periods, but will not probably remove the foundation upon which they are based.

70. The foregoing divisions are subdivided into systems. These subdivisions are intended to be founded upon the intimate relations which their organic remains hold to each other. The beginning and outgoing of a system are marked by physical changes. The condition of the sediments indicates changes in the earth's crust, and a violent movement of the waters; hence beds of coarse and fine pebbles, or conglomerates, constitute the physical boundaries of systems, and a change in the organic contents more or less extensive appears in the fauna preserved in the adjacent systems.

71. The beginning of a system is usually marked by the appearance of certain important fossils, which are also confined or limited to its special range. A system then is represented by a series of rocks

which contains fossils peculiar to it, and they are collectively regarded as representing a particular era.

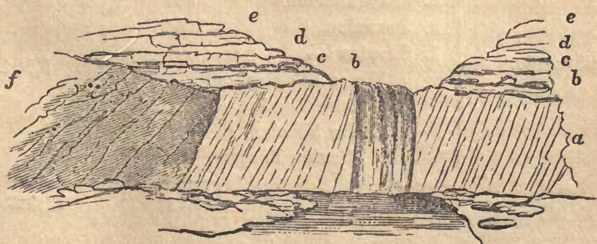
The order of the systems is represented in the annexed geological column.

Each general division includes several subordinate systems. It is convenient also to subdivide the systems into *upper*, *middle*, and *lower*, as the upper, middle, and lower sections of the Silurian or Devonian Systems, as it enables the geologist to particularize the fossils characteristic of each section, if necessary, or if they admit of it.

The Pyro-plastic System is often intercalated irregularly with all the systems, as intruded igneous masses. It is of all ages. It has no constant position, yet there are certain epochs in which the traps and porphyries were ejected in greater force than in others. These seem to have been eras of great disturbance, and are characterized by outbursts of molten matter.

CAINOZOIC.
Pleistocene.
Pliocene.
Miocene.
Eocene.
MESOZOIC.
Cretaceous.
Jurassic.
Triassic.
PALÆOZOIC.
Permian.
Carboniferous.
Devonian.
Silurian.
Taconic.
Laminated or Gneiss System, Massive Pyro-crystalline System, Granites, &c.

Fig. 36.



Unconformity of the Lower Silurian with the Gneiss at Montmorency, Canada East.
e, d, c, b. **Lower Silurian.** *a.* **Gneiss.** *f.* **Black Slate.**

72. *Table of Formations and Stages according to D'Orbigny.*

FORMATIONS.	STAGES.	No. of Mollusks in the Stages.	Total number of species of animals known to D'Orbigny in 1850 in the formations.
Contemporaneous.	28. Contemporaneous with the present epoch.		
Tertiary.	27. Subapennine.	444	6,040
	26. Falunian.	2903	
	25. Parisian.	1478	
	24. Swessonian.	562	
Cretaceous.	23. Danian.	47	4,098
	22. Senonian.	1061	
	21. Turonian.	218	
	20. Cenomian.	627	
	19. Albian.	307	
	18. Aptian.	146	
	17. Neocomian.	656	
Jurassic.	16. Portlandian.	59	3,785
	15. Kimmeridgian.	184	
	14. Corallian.	403	
	13. Oxfordian.	499	
	12. Callovian.	253	
	11. Bathonian.	407	
	10. Bajocian.	508	
	9. Toarcian.	273	
	8. Liasian.	270	
	7. Sinemurian.	163	
Triassic.	6. Saliferian.	619	840
	5. Conchylian.	104	
Palæozoic.	4. Permian.	82	3,184
	3. Carboniferian.	887	
	2. Devonian.	1054	
	1. Silurian:—		
	Upper Silurian, or Murchisonian.	356	
	Lower Silurian, or Silurian Proper.	375	
		14,947	17,947

CHAPTER VII.

CLASSIFICATION OF THE PYRO-CRYSTALLINE ROCKS—AGE OF GRANITE AND ITS ASSOCIATES—SUCCESSIVE FORMATION OF GRANITE AND ITS DISTRIBUTION—INDIVIDUAL ROCKS DESCRIBED, ETC.

73. THE classification of rocks is in part based upon the forces or agents which have been described. There are strictly only two classes: first, embraces those whose structure and position clearly prove that they have been melted or partially fused. These have been named igneous, or *Pyro-crystalline* rocks. Second, those which are evidently *Sediments*, or have been deposited from water: they have been called sedimentary, *Hydro-plastic*, and often termed *Stratified* rocks. The first class is subdivided into three systems: the *Massive Pyro-crystalline*, the *Laminated Pyro-crystalline*, and the *Pyro-plastic* rocks. The first system embraces granite and granitoid rocks, among which we may rank Syenite, Hypersthene rock, and Pyro-crystalline limestone, with their subordinates, the Magnetic and Specular ores of iron, Serpentine and Rensselaerite.*

74. *Granite.* Common Granite is composed of three elements: *Quartz*, *Feldspar*, and *Mica*. These elements are variable in size and proportions. They may be very coarse or fine, or any intermediate degree of coarseness. Each of the constituents may in different localities predominate over the others, and produce varieties of granite. The feldspar may predominate and hornblende take the place of the mica; this composition is called Syenite. The color is gray, flesh-color, or quite red. The feldspar imparts the color: the quartz is invariably gray.

The feldspar, mica, and hornblende are crystallized, but the quartz never, and is frequently impressed both by the mica and

* We do not recognise metamorphism as a suitable characteristic upon which to base a classification, as any rock may be metamorphic.

feldspar, which seems to indicate that the feldspar and mica cooled and crystallized, while the quartz continued plastic.*

75. Granite and other pyro-crystalline rocks separate into angular blocks after long exposure to atmospheric influences. It is undoubtedly due to crystallization of the mass. There is also a separation into beds, which resemble the thick beds of sediments. Several may be observed parallel with each other. They are not due, however, to stratification, as they are always parallel to the slope of the surface where they occur. Fig. 37 shows the structure of granite

Fig. 37.

Structure of Granite.

and granitoid rocks, as it is nearly uniform in the whole class. The first appearance of the division of the mass is merely in lines; subsequently, disintegration takes place along those lines, and the blocks are finally separated. The fine or middling granites occur in beds extending over large areas, but the white and coarsest kinds are limited, and are usually in veins in other rocks, particularly in mica and talcose slates and gneiss. The white coarser granites are most frequently the repositories of other minerals, as tourmaline, beryl, quartz crystals, large plates of mica, spodumene, &c. Tin is supposed to belong to the syenitic granites, though it occurs in small crystals, in the coarse granite of Chesterfield and Goshen mass.

76. *Age of Granite and its associates.*—Granite forms the high-

* Quartz is much more refractory in the fire than feldspar or mica; but quartz undoubtedly retains its fluidity after these have been consolidated, or is longer in cooling.

est peaks of mountains, and may be regarded as among the highest rocks geographically, and is also known as the lowest or to exist beneath all others, and hence is probably the oldest; yet it is intruded among all the later rocks down to the time of the deposition of the chalk. We may therefore speak of the newer and older granites, inasmuch as they appear to have been formed during all periods of the earth's history down to the chalk. Its relative age, therefore, is determined only from the rocks with which it is associated.

Many localities in Massachusetts show masses of granite reposing upon the nearly vertical lamina of mica slate.

77. The oldest granite appears upon and forms the highest mountain peaks. These, on cooling, became fissured and cracked, through which newer granites were ejected. Fig. 38 illustrates the succes-

Fig. 38.

Successive Formations of Granite.

sive formations of granite cooled from above downward, the later beds sending veins into the older, which are above them. The diagram also represents the order in which the hypogenic rocks may be formed. The granites may therefore increase in thickness by accession of matter both from above and below.

78. *Distribution of Granite.*—The coarse varieties of granite occur in Chester, Russel, Norwich, Chesterfield, and Goshen, Massachusetts. Paris, in Maine. Fine granites have long been known and quarried for building in Quincy, Chelmsford, Fitchburgh, and Sharon. In Maine at Hallowell, and other places, the same fine beautiful varieties occur. These varieties hold remarkable relations to other rocks. They overlie and rest upon them. The matter composing these beds issued from fissures in the rocks upon which they rest and overflowed large surfaces. Near Augusta and Hallowell, Maine, in Warren County, North Carolina, this kind of granite may be seen reposing upon the highly inclined lamina of mica,

slate, gneiss, and hornblende. In the Southern States the first or most easterly range of granite appears on a belt separating the low country from the upper, as at Richmond, Va., Weldon, Rockymount, and vicinity of Buckhorn in North Carolina.

79. The Hoosick and Green Mountain range, the Blue Ridge passing through the Middle, Southern, and South-Western States, furnish many localities of granite. In Caldwell and Wilkes counties in N. C., heavy beds of porphyritic granite flank the Blue Ridge on the eastern slope, and occupy a part of the upper valley of the Yadkin. They are rarely the depositories of valuable minerals.

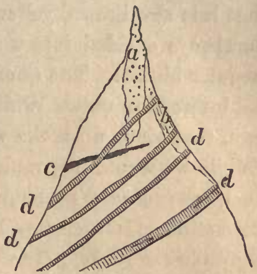
80. *Hypersthene Rock.*—This rock has the common structure and appearance of granite, but contains less mica and quartz; indeed it is composed mainly of Labradorite, and a small quantity of Hypersthene. In the fine grained varieties large crystalline masses are imbedded, which gives it a resemblance to porphyritic granite. Its colors are variable; light gray, passing into dark smoke gray. The Labradorite is blue and bronze or yellowish, and takes a fine polish, and is beautiful for ornaments. There are several compounds worthy of notice. Labradorite and hornblende, hornblende and epidote, granular Labradorite and mica, with disseminated grains of magnetic iron.

Distribution.—It is confined mostly to the Adirondack Mountains of New York, and contains large beds of magnetic iron ore.

81. *Pyro-crystalline Limestone.*—This rock has the structure of granite, and often has a granitoid appearance. It is massive and like granite, and divides into angular blocks, and, as it is usually associated with the older rocks, its age is not determinable except relatively. It has been mistaken for a *Silurian limestone*, but at several localities in northern New York the Potsdam sandstone rests upon it. So, also, it is found evidently ejected from fissures in the hypersthene rock, in which case it is an igneous rock, resembling in structure the coarse granites of New England. So, also, it occurs in distinct veins or dykes; hence it is necessary to describe it as a pyro-crystalline rock. Its relation to granite is shown from a locality in Chesterfield, Essex County, N. Y., where it underlies granite. Many others might be cited. It also occurs in veins near Rossie, St. Lawrence County, New York. It protrudes through hypersthene rock at Long Pond, Essex Co., as represented at *a* (fig. 39). Its relation to the Potsdam and calciferous sandstones at Moriah, Essex Co., where it is associated with hornblende and gneiss, proves

that it is not an altered Silurian rock, as the former rest against the latter. Fig. 40 *a*, Potsdam and calciferous sandstone: 1-1, hornblende; 2-2, pyro-crystalline limestone; 3-3, gneiss. It is evidently an intruded rock. Other rocks occur in isolated masses in this limestone. Fig. 41 represents an instance occurring near Port Henry, Essex Co., N. Y.: *a*, limestone; *b*, hornblende.

Fig. 39.



a Limestone at Long Pond.

Fig. 40.

Moriah Section.

Compounds of limestone and serpentine are common in Northern New York, in Essex and Warren Co. It forms the ophicalce of Brogniart. Its relations to other rocks do not differ from the pure unmixed limestone. It may be polished when it forms the serpentine marbles, which are quite ornamental for parlor tables and mantel pieces.

Fig. 41.

Isolation of other Rocks in Limestone.

82. *Localities and Distribution.*—The massive kinds occur in St. Lawrence, Essex, and Warren counties of New York, also in the highlands of the Hudson River, and in Sparta and Sterling in New Jersey, and other places.

This rock is rich in minerals. Of the metallic oxides it contains iron, zinc, franklinite, and sphene. Of the order Gem, blue and red corundum, spinelle, zircon, brown tourmaline, and quartz. Of the order Haloide, phosphate of lime, calcspar, mica, and graphite are also common in this rock: the latter seems to be a characteristic mineral.

83. *Serpentine.*—This rock is unlike granite, as it is always

homogeneous and has a fine grain. Its predominant color is green, but it is also brown, yellowish brown, and black. A mountain mass is always divided into wedge-form fragments, never cubical or in regular blocks. The question respecting the origin of this rock is an interesting one. While we have some doubts of its igneous origin, that view, upon the whole, is better sustained than any other. While we would not rank it positively in the pyro-crystalline system, we can scarcely doubt that heat has had much to do with its formation. It seems to be closely related to the trappean or the pyro-plastic rocks. The existence of silicious layers and lamina often drusy, together with calcedony and minerals of this order, indicate that serpentine may have had an intimate relation to ancient hot springs.

84. It occurs in the midst of other rocks in a manner similar to those which are known to be intruded or eruptive ones. Serpentine veins are rare; and it is also rarely a metamorphic rock, as at Syracuse in New York.

The minerals contained in serpentine are the ores of chrome and magnetic iron. The latter exists in a large vein at Troy, Vt.: it is also disseminated through the rock at Middlefield, Mass. Lead ores occur in it in North Carolina. Diallage and schiller spar are its most common earthly minerals. Native gold has also been found in quartz veins in this rock.

85. *Distribution.*—It occurs at New Fane, Vt.; Middlefield, Chester, &c., in Massachusetts. It is common along the entire range of the Alleghanies in Pennsylvania, Delaware, Maryland, Virginia, North Carolina, &c.

Rensselaerite.—This rock resembles a compact serpentine; it is greenish, gray, and sometimes black. Its hardness is about equal to fluor spar. It is homogeneous. It is composed of silica, magnesia, lime, oxide of iron, and water. It seems to belong to the intruded or eruptive rocks. It occurs in large beds at Russel, St. Lawrence Co., N. Y.

86. *Magnetic Oxide of Iron, or Octahedral and Rhombohedral Iron Rock.*—Octahedral iron rock occupies a large area in the Adirondack Mountains in Northern New York. It has a structure quite similar to the hypersthene rock in which it occurs.

The Rhombohedral iron rock is less extensive, but is sufficiently so to merit a place among the constituent masses of the globe. It

is associated with the serpentines and pyro-crystalline limestone of St. Lawrence Co., N. Y.

Masses of iron occur at the Parrish iron mine, St. Lawrence Co., in a position which shows that the ore was protruded subsequent to the deposition of the Potsdam sandstone. The rock in this case being disturbed at the time of its eruption.

Fig. 42.

Atlantic Currents.

CHAPTER VIII.

SECOND SYSTEM, THE LAMINATED PYRO-CRYSTALLINE ROCKS, GNEISS AND ALLIED COMPOUNDS.—THIRD SYSTEM, THE PYRO-PLASTIC ROCKS, BASALT, GREENSTONE, TRAPS, PORPHYRIES, ETC.

87. THIS system embraces gneiss, mica slate, hornblende rock, and talcose slate; sometimes they pass into quartz. To the foregoing it is necessary to add limestone and serpentine, inasmuch as both have a laminated structure under certain circumstances.

88. *Gneiss.*—Gneiss has the same component elements as granite, but they are arranged in parallel lines or bands; and hence it has a very close resemblance to a stratified rock. Indeed, it is placed by many in this class. But we believe its structure is due to the circumstances under which it cooled. Thus, its laminæ are always made up of different crystallized minerals, which, while undergoing this process, separate from the mass to that extent that the layers become individualized. There is probably also a state of tension occasioned by the pressure of the mass beneath.

89. That there is a force competent to arrange the elements in distinct bands, when they are intimately mixed, is proved by many examples: the flint of chalk beds, the septaria in slate, and the silicious nodules of the carboniferous limestone, are examples in point. In these instances we are obliged to recognise a force which separates one mineral from another, as silex from clay, or silex from limestone, or carbonate of limestone from clay. In all these instances layers or nodules may be formed. The laminæ of gneiss do not differ so widely from those produced by the molecular force, to which we have referred, as to prove that their occurrence need be assigned to a different cause, as that of deposition.

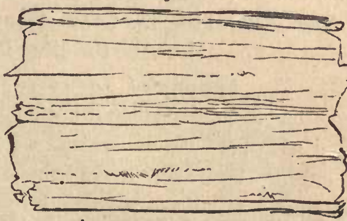
The same force has operated also in mica and talcose slates and hornblende rock.

Gneiss is a granitoid rock, and frequently passes into granite; and it is probable that the former may be regarded as the superior part of a mass of granite. In other instances it is inseparable from mica slate, and others which belong to this class.

This rock is also porphyritic: crystals of felspar stand out upon its surface in consequence of weathering, while the laminæ are quite distinct. It often resembles granite, and large areas of such a mass may be a true granite; the size and numbers of the individual crystals obliterating the laminated structure.

Fig. 43 represents the parallel arrangement of the minerals composing a mass of gneiss. The laminæ, however, are not always straight. They often exist in curves or folds, or even in zigzag lines. A mechanical force seems in many instances to have produced these varieties.

Fig. 43.



Structure of Gneiss.

90. *Mica Slate.*—Typical Mica Slate is composed of quartz and mica. The color is gray, varying from light to dark. It has a shining appearance and strong lustre. The mica is usually in small particles; talc is often intermixed with it, and small crystals of hornblende are also often found.

91. *Hornblende Rock.*—In this rock Hornblende exists in large proportions, intermixed with grains of feldspar, quartz, mica, and talc; but hornblende and feldspar predominate and generally compose the entire mass. The color is usually dark green. The arrangement of the minerals is similar to that in gneiss; the feldspar and hornblende being arranged in separate planes.

92. *Talcose Slate.*—This rock is composed of quartz and talc. The quartz predominates; but the talc being more conspicuous, imparts its own character to the rock. It is of a light greenish gray color with a silvery lustre. The laminæ are frequently corrugated; the corrugated condition is far more constant in this rock than in mica slate, or gneiss. Beds of closely compacted talc form the well known soapstones. Beds in which talc is almost entirely excluded, form a variety of quartz rock, which may be mistaken for a sandstone of sedimentary origin, as at Pilot Knob in North Carolina. Milky quartz is a common mineral in the talcose slates. It occurs in irregular seams. Fig. 44, *a*, *b*, *c*, shows the structure of granite, gneiss, and talcose slate.

93. *Distribution of Gneiss, Hornblende, Mica Slate, and Talcose Slate.*—These rocks, with a few exceptions, form the White Hills

Fig. 44.

a Granite. *b* Gneiss. *c* Talcose Slate.

of New Hampshire, the Green Mountains of Vermont, the Hoosic Range of Massachusetts, the Blue Ridge of the Southern States.

94. *The Laminated Limestones and Serpentine.*—There are numerous instances where Limestone and Serpentine are interlaminated with the foregoing rocks. In most cases they partake of their structure. This structural phenomenon is not well understood, and it is necessary only to refer to the fact and state one or two localities. The limestones of Middlefield, Mass., where it is crossed by the Western Railway, is a good example of this variety of limestone: and an extensive bed of serpentine in Macon Co., N. C., is a remarkable one for serpentine. In this connection we may observe that trap and porphyry sometimes appear like the laminated rocks, as at Essex on Lake Champlain.

95. *Metals, Ores, and Sulphurets of this System.*—Gold, in the Southern States, the eastern slope of the Green Mountains, and in Canada, is a common product. It is sometimes contained in pure quartz, white as loaf sugar, and also associated with the sulphurets of iron and copper, and is no doubt in chemical combination with sulphur, as it is impossible by mechanical means to separate the gold from the sulphurets or sulphides.

96. *A Summary of the Leading Facts respecting the Pyro-crystalline Rocks, or those composing the First and Second Systems.*—

Division.

PYRO-CRYSTALLINE.

Structure.

1*st.* *Massive Pyro-crystalline.*	2*d.* *Laminated Pyro-crystalline.*
Names.	
Granite and Syenite.	Gneiss.
Pyro-crystalline Limestone.	Hornblende Slate.

Serpentine.	Mica Slate.
Rensselaerite.	Talcose Slate.
Octahedral Iron.	Laminated Limestone.
Hypersthene Rock.	Serpentine.

Remarks.

May be intrusive, but are often overlying.	Usually overlying, but do not occur in a certain order, and never intrusive.

Fig. 45.

Adirondack Pass. Cliff of Hypersthene rock, 1000 feet perpendicular.

CHAPTER IX.

THE PYRO-PLASTIC ROCKS.

97. This series of rocks are distinguishable from the pyro-crystalline by the state of aggregation in which they exist. They are more homogeneous and compact than common granite, and crystals of feldspar are common as in the porphyries. Fig. 46 represents an instance where angular masses are imbedded in a compact paste.

Fig. 46.

Porphyritic Structure.

These rocks should be divided into two groups: 1st. the *Submarine*, 2d. the *Subaerial*. These names indicate the circumstances under which they were cooled. Those belonging to the *Submarine division*, the basalts, greenstone, amygdaloid, trap, porphyry, and clinkstone, it is supposed were erupted under the waters of an ocean, or cooled under a great pressure.

Basalt is black, fine grained, and compact; it is both massive and columnar.

98. *Greenstone and Trap.*—Greenstone differs from basalt in being somewhat crystalline, and usually contains crystallized particles, but to the unassisted eye it is in the main homogeneous. When these form masses which are confined or bounded by parallel walls, composed of other kinds of mineral matter, they are called trap dykes. Dykes are sometimes slightly columnar. (Fig. 47).

Trap and greenstone are often vesicular, and the vesicles are filled with foreign matter; this is called amygdaloid.

99. If masses ring when struck with a hammer, it is called clinkstone.

Fig. 47.

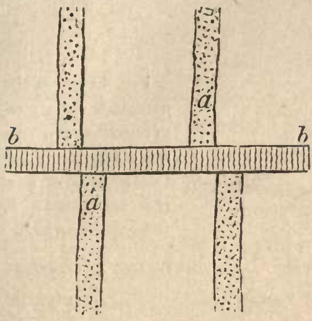


Fig. 48.

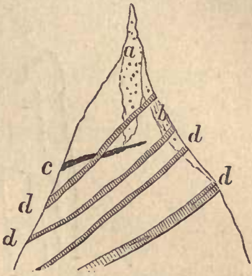


Fig. 47 represents a trap dyke. *a, a,* granitic veins: *b,* trap dyke. It will be seen the trap cuts the granite veins; showing that the trap was injected subsequent to the granite. The figure shows that a dislocation or shift has taken place.

Fig. 48 represents trap dykes intersecting other rocks: *a, b,* mass of pyro-crystalline limestone, *d, d, d,* trap dykes; *c,* a vein of octahedral iron.

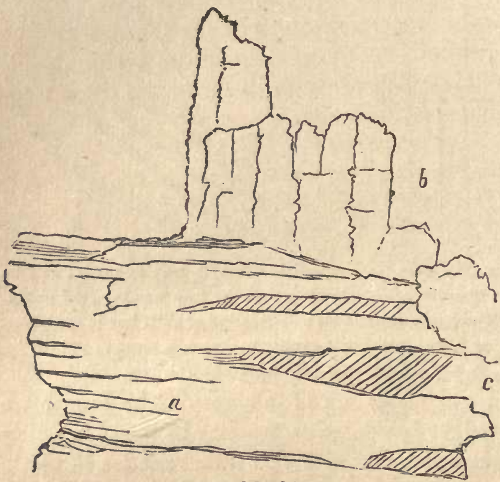
Trap dykes and greenstone are of all ages. The former are formed in nearly straight fissures, and often may be traced in nearly a direct line for many miles, and with very little variation in width.

100. *Origin of this Series.*—All the varieties which we have described are igneous products, and have issued from the interior of the earth through rents. The molten matter has overflowed the surrounding surface, or has been forced between the strata of other rocks. The upper surface has in some instances been comparatively free from pressure, and the confined vapors expanding have formed cavities, as in the amygdaloids. These cavities were afterwards filled by transfusion through the mass of rock by means of water carrying in solution the elements of various bodies, as analcime, stilbite, calcspar, prehnite, &c.

101. *Subaerial Division.*—The rocks belonging to this division include lavas and all matters which have issued from the craters of volcanoes. Flowing in a liquid form, large areas are often covered with the molten rock. When cooled and solid, it is black, porous, and vesicular or homogeneous, vitreous or similar to the slags from a furnace, and beneath, in consequence of the pressure of the superincumbent mass, it is nearly compact; its vesicularity increases from the bottom to the top, (fig. 50); *c,* columnar greenstone; *b,* porphyritic; *a,* lava. Ashes and stones also issue from volcanoes which fall in part around the orifice and form a cone, or are carried by winds to neighboring parts, or even to distant countries. Pumice is a light gray fibrous glass; so light as to float

upon water. Obsidian is a volcanic glass and free from vesicles, and breaks with a conchoidal fracture.

Fig. 49.



Trap and Sandstone.

Fig. 49 shows the columnar variety of green-stone; *c* is a mass forced in between beds of new red sandstone; *b*, the columnar part.

Fig. 50.

a. *b.* *c.*

102. *Tabular View of the Members of this System.*

Origin.

Igneous.

Division.

PYRO-PLASTIC.

	Names.	*Remarks.*
1. Submarine.	Basalt. Greenstone and Trap. Porphyry. Clinkstone.	Erupted through fissures and cooled under pressure. Structure compact; sometimes there are crystals in a compact base. When vesicular, the cavities are lined with crystals.
2. Subaerial.	Lava. Ashes. Pumice. Obsidian.	Erupted through craters and cooled in the air, and more or less vesicular.

CHAPTER X.

OF THE SEDIMENTS OR HYDRO-PLASTIC ROCKS—AGENTS CONCERNED IN THEIR PRODUCTION—RECOGNISABLE BASE—PROGRESS OF LIFE DURING THE SEDIMENTARY PERIODS—AMOUNT OF SEDIMENTS—GEOLOGIC TIME.

103. It was an important era when vapors began to condense upon the earth's surface. It ushered in a period distinguished by a new class of phenomena. The earth felt the animating effects of this new agent; and these effects must be regarded as indicative of progress.

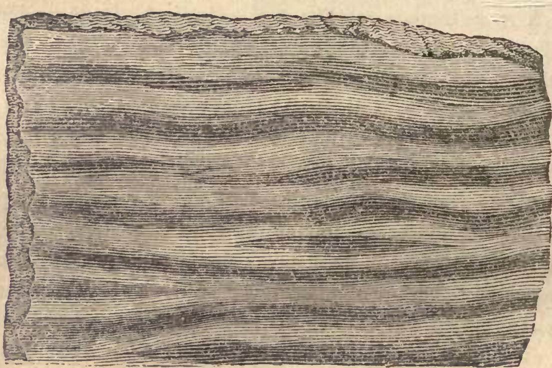
104. The sediments are due to mechanical causes, and mainly to attrition. Atmospheric agencies are preparative, as by them the surfaces of rocks are altered, and the adhesion and force of aggregation among particles is diminished and even destroyed; and hence falling water, as rain, running water, as in brooks, water moving in mass, as that of tides and waves, are much more effective than if left simply to its own mechanical powers. Atmospheric agencies are much more active on mountains than elsewhere. The moist surface and the effect of frost break down rapidly many kinds of rock, especially those which contain alkalies and alkaline earths. If they are jointed, they are slowly reduced in size, and the angular blocks are separated; but if they consist of silex, they may resist disintegration for centuries. Granites are more subject to change in consequence of their composition; and schistose rocks, such as mica and talcose slates, from their structure and component parts. But, whether rapid or slow, the broken rocks tend to the valleys; and the streams, which often rush forward with a mighty force from the hills, are constantly employed in carrying debris from their tops and sides to the rivers below. The special destinations are to the plains, where the debris may be left; or lakes, through which they flow; and, finally, the ocean, where all the waters ultimately bring their burthens. The fine particles are committed to the waves, tides, and ocean rivers, or the deep and superficial currents, and thereby reach those destinations which gravity and the direction of the moving waters may determine.

The waters of the ocean are distributive, while streams and rivers

are transportive. To the combined effects, then, of streams, rivers, and ocean currents, is due the accumulation of the sediments. While their activity has been unceasing and continuous, the period during which they have thus moved is susceptible of divisions into stages, each of which is distinguishable from the rest. The sediments are monuments constructed by the agents already described: or they may be viewed in the light of tablets upon which are recorded the entire history of the sedimentary period.

The peculiar phenomena which belong to sediments, as a whole, are the presence of *pebbles, fossils, and ripple marks,* especially the two former: the latter is the most common in sandstones: fig. 51 illustrates this character.

Fig. 51.



Ripple Marks.

Of the sediments we maintain that we have a recognisable base, the visible beginning of a vast period; and if so, it follows that we have also a palæozoic base, to which we may point as the beginning of the organic kingdoms when the creative acts of God spake life into dust, from which successive acts both of creation and generation have made the earth a scene of activity, harmony, beauty and progress. It is harmonious, for life in all its forms and phases has been adapted to every special physical condition. It has been progressive, for creation began with the lowly organized tribes, and proceeded to the higher, by successive upward steps, ending with man, whose superior rank is strikingly told by his erect body, ponderous brain, and upward directed vision.

The life eras both of plants and animals began at the extreme end of the scale. As eras, their beginning is marine, and the pecu-

liar and distinguishing forms of life were obscure and lowly organized fuci, or the coral and crinoid, whose functions partake largely of the vegetable kind, or those only which belong to the lowest rank.

105. Instinctive movements, and those of the nutritive functions alone, distinguished them from analogous vegetable forms; and though all were perfect, and well adapted to fulfil the ends of their existence, still the survey of long periods is required, before we discover the higher organizations indicated by the soft and solid parts,—*brain and bone*,—with their appendages; combinations, necessary it would seem, for a more vigorous exercise of physical force as well as the higher adornments of life. Often, however, progress is at a standstill, or creeps lazily forward in doubtful garbs or habiliments; some of which are frequently suspected to have been *indicative of degradation;* but a deeper insight into structure, form, and combination proves, that nature is moving on slowly, but with progressive steps, to that goal of perfection which this system of arrangements is destined to attain.

When trees and forests adorn the earth, the sediments have already attained half their thickness, and it is only in the middle periods that *reptilian* life, a second stage in advance of the vertebrates, is represented in the ancient earth's fauna. Not even birds, or any vertebrates with warm blood, are yet living, and when they appear in the Mesozoic division, they belong to the lowest of their respective classes; and it is only in the Cainozoic division, that the rocks disclose to us the highest grades of structure, combined with a development of brain and bone indicative of intelligence, social habits, and a love of kind.

Thus, though at first the life forms are beautiful without and within, *as structures*, yet they exhibit no results belonging to brain-influence. They are only vegetative beings guided by instinct. Thus, comparing the extreme with the middle, and the middle term with the present or the Cainozoic, the proposition, that life has been progressive and developed in stages, is as well established as any connected series of events in the history of the by-gone nations of the East.

106. The characters of the sediments vary with the source from whence they were derived, and the force of the transporting agent. With every change of level, new kinds of sediment are borne forward, and, accompanying this change, the sediments are necessarily coarser. If a change of level is considerable, the direction of all

the surface streams is changed also; and as their motions must be tumultuous, stones and rocks are transported, and, hence, the conglomerates are formed which usually mark the beginning of a new era. These changes of level of the earth's crust seem to have been incompatible with the existence of the species then living upon the area affected; and, hence, extinction follows the change.

When the waters move quietly again, we find that new species are created fitted to take the places of those which have perished. It is a part of the duty of the geologist to note particularly those physical changes by which new kinds of matter accumulate, and new living species are taking the place of those which have passed away.*

A succession of beds, or of rock, is no doubt to be attributed *mainly* to the changes of level, in the earth's crust. And so, also, we may assume, the succession of fossil remains is due, in part, tc the same cause.

107. Sediments are usually deposited in parallel beds; but not always. When they are deposited from tumultuous waters, or when deposits are undermined, and their position is changed, it often happens, that the beds exhibit a diverse stratification, as represented in Fig. 52.

Fig. 52.

Diverse Stratification.

Sediments, we have said, have not always been deposited *horizontally.* Such a view is disproved by observations upon a sea-

* It is evident that changes of level have affected and will affect those mollusks which inhabit shallow water, while those which inhabit deep seas may escape the injurious effects incident to a moderate change of level. But those inhabiting the deep parts of seas would not probably escape *entirely* from the disastrous effects of a change of level, since the waters would be less deep, and since, too, they are fitted to those greater depths rather than those which are shallow. So, also, great subsidences of the ocean's bottom, have been equally destructive to life. We may, therefore, regard the position as established, that changes of level have been the principal cause of the extermination of marine animals in former periods.

shore, when the surface, or bottom, is inclined sometimes steeply; and yet deposits are taking place upon these slopes. Inclined beds, therefore, are formed during their deposition upon the borders of an ocean, without having been subjected to an upheaval. Various changes, too, affecting their position, are going on; portions are washed away, forming thereby depressions; prominences are sliced off, and yet the process of deposition goes on. Hence, there may appear to have been breaks, and certainly many curious unconformities will occur, especially in sandy deposits. Sediments, then, cannot be represented by a pile of books stacked up in exact order. So, too, beds may be elevated over a large area and cease to receive accessions of sediment. These, in after times, may be depressed, and again, when debris accumulates, they are placed in a true unconformability. Between their elevation and their going down, or during the time they were dry land, distant sediments have accumulated in which animals and plants are preserved, and which thereby become the historic records for this interval.

It follows, then, that geologic history is often incomplete in the sediments of one country. Who would expect to find a complete history of the American Revolution in our own archives? For that we go to England, France, and Germany, in order to complete the record of events for a few years. The sequence of geologic records is complete, the sequence of events, too, is complete, but not in any one country, yet sediments are frequently deposited in horizontal layers; they belong to the deep sea, far from land, and away from the influence of tides and currents.

108. *Amount of Sediments.*—It is impossible to calculate accurately the quantity, or mass of the sediments. The area occupied by the mountain-chains upon the globe, is small compared with the extent of the plains and gently rolling surfaces. Besides, the sea conceals and covers, no doubt, a much greater amount than is lifted above its level. It is true, that over large areas the sediments are thin, especially those belonging to the latest periods. But it is stated, by good authority, that they are at least ten miles thick,—a statement which is, no doubt, below the truth; but if this is received as an approximation to the truth, it is evident, that the sediments are sufficient to form more than a score such mountain systems as those which now exist.

Then it is to be remembered, that it has all been mechanically worn from preëxisting rocks; and when it is considered, that a

single sandstone rock, composed only of some hundred layers, must have occupied a long time in its deposition, we may feel satisfied, that we are not presuming too much, when we assign an immense or inconceivable lapse of time to the period which has been consumed in the deposition of all the sediments.

The facts relative to the amount of sediments bear directly upon the question relative to the age of the world, and especially to the time which has elapsed since the earth became inhabitable. The approximate estimation, then, fully warrants the conclusion we have stated.

Vegetable and animal life also confirms the proposition, that the time since this creation began was immense.

109. In the foregoing sections reference has been made to geologic time. Time, when referred to, implies, in common usage, a period which can be measured; and the first idea of the student in geology is, that geologic time is measured, like secular time, by the year and its parts. Attempts have been often made, to convert geologic time into secular; that is, to compute the epochs, or periods, by years. But these attempts have failed. Time in geology, is not absolute, but relative. Time considered in human affairs, is both absolute and relative; and it is absolute, because it has its *units.* A rotation of the earth upon its axis is the unit, and its revolution around the sun is something more than 365 of these units. These revolutions and rotations express constant and ever recurring periods. All events, which have transpired since man was created, have a fixed relation to these units. As regards man and events, there is a unit and a known starting point. Now, geologists have failed in attempting to compute by absolute time, because they could neither obtain a unit nor a starting point. Sir Charles Lyell has counted the layers in the sediments of the delta of the Mississippi, and measured the suspended mud in the waters which it brings to its delta and to the sea. Rationally, it carried him back 40,000 years since the delta began to form; but his unit was a layer of mud, and hence, when all the circumstances are considered, is entirely problematical, or approximative only. So, also, he has counted the steps of the Niagara as it has receded from a lower towards an upper lake. But here the steps are unequal, and hence gave him no unit in its march. Unlike the earth and planets moving in their orbits and completing their revolutions in equal times, we find that all geological movements are

too unequal from their nature and so much exposed to perturbations, that geologists have failed to obtain an exact unit by which they can measure periods or epochs. Geologic time is, therefore, relative; and all epochs and periods have relations in time to others, and are never computed in years or definite cycles.

110. While then we speak of geologic time as relative, because we have no unit to measure it by, we cannot fail to discover in the sequel, that it is really vast; or, indeed, scarcely measurable at all. Indeed, geologic time is only comparable to astronomical space. It is, however, not like space, *infinite*, but it is vast. We obtain an approximate measurement of time by masses of sediment which have accumulated during the epochs; each of which must have been vast also. The mode of measurement is analogous to that pursued by astronomers. It is a division of masses into stages, which are separably, and also, in the aggregate, more comprehensible, than if we attempted to conceive of them in their totality. The beds composing the Silurian, Devonian, and Carboniferous rocks, which may be regarded as portions of space, represent, in one sense, time, are measurable; and if we assume, as probably we may, that the past was like the present in its modes of action, it follows, if we have observed and measured the progress of the present, that we may obtain approximate ideas of the past. But, then, we are ever brought back to the *vastness* of geologic time, precisely as the astronomer, who gauges the depth of astronomic space without ever being able to measure the bounds in which matter is distributed.

111. There is no fact which is better established, than that of a succession of organic beings. It rests on evidence equally firm, as the succession of rocks. Succession and replacement are the two great geological facts. As we have already intimated, the physical changes are also successive; but there is something more in geological succession than the word seems to imply;—the succession is one that advances from a stage of disturbance to one of rest; from imperfection to perfection; and each change is itself a progress, and it is also preparative. But progress is often confined to *specializations*, and this has often deceived philosophers; for, though it is usually the highest evidence of progress, it has sometimes been confounded with degradation. Geologists, recognising the principle of succession, have sought, with avidity and success, the chronology of organic beings, or the time when the families,

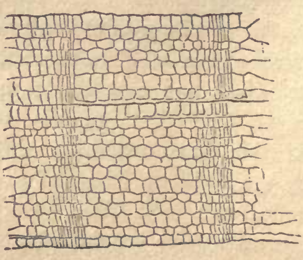
composing the organic world, first appeared, and also, in connection, the doctrine of *replacement*, have sought to determine when they disappeared, and who and what replaced them in the succeeding group.

But there is a more general view than the preceding, as it regards succession. It goes further back. It takes in the consideration of the elementary tissues. Animals, as we have seen, are composed of muscle, nerve, bone, &c. At what period did bone and brain appear, for they go together; for though the nervous system existed from the beginning in some low stage, yet, bone and brain proper, seem to be linked together in time. Cellular tissue is the connecting structure for all organs, and is no doubt the oldest of all. In plants, we have the *cellulares*, which represented at one period the whole vegetable kingdom. But there are particular modifications of cellular structure which are not thus universal. Thus the peculiar structure of bone is confined to bone; bone-cells are confined to, or limited to bone; and animal structures, taken in classes, have each their peculiar modifications. The bone of the bird, for example, may be distinguished from the bone of a quadruped; and the bone of the fish, also, from the other classes. But the most interesting fact representing bone structure and bone-cells is, the *permanence* of the pattern. For example, the bone-cells of the earliest fish cannot be distinguished from fish of our rivers and oceans. The bone-cells or the cells of any tissues, have not changed in time. Hence it is, that uniformity has been preserved, as the structures are built into forms complete, and yet the plan is not altered. The external form may be changed, yet the intimate structure is now what it was in the days of the Old Red Sandstone, or Carboniferous system.

Fig. 53.

Ancient Conifer.

Fig. 54.



A Living Conifer.

To show this fact we have placed side by side the ancient conifer (fig. 53), with the conifer of our present forest (fig. 54).

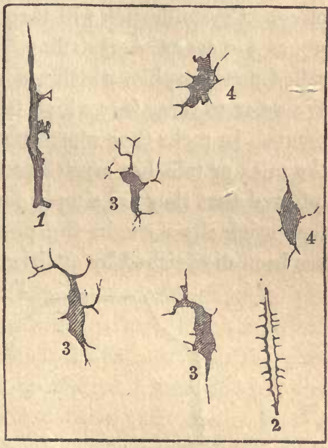
112. So also the bone of an ancient reptile is

identical with the bone of the reptile of the nineteenth century: fig. 55, bone cells of an ancient fish: fig. 56, 1, bone cell of a recent fish: 2, of a reptile: 3, of a bird; 4, of a mammal. There have been myriads of organic existences, yet there has been no deviation in the patterns of structure. In all the ancient or extinct beings, the pattern has been followed throughout in the modern; and hence to find original types we have to go back; and our language should indicate a comparison of the present with the past, and not the past with the present.

Fig. 55.

Bone Cells of Ancient Fish.

Fig. 56.



Bone Cells of Fish, Reptile, Bird, and Mammal.

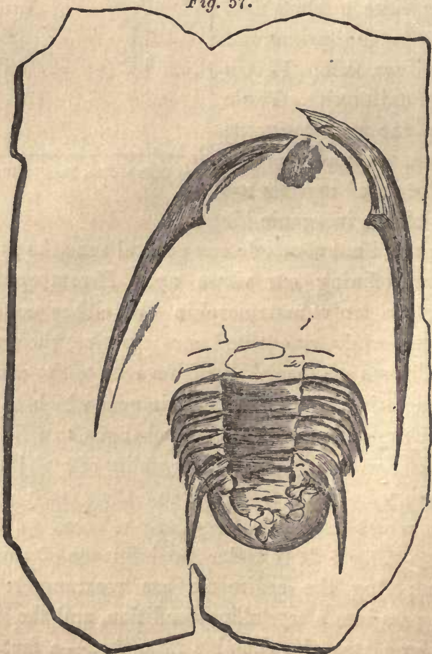
To preserve these uniformities, as they exist in the primordial types, required *one will.* This is the essential of uniformity. These structures are the real constants of organization, as much as the determinate forms of crystals are the constants of the inorganic kingdom.

112. We should not conclude our general remarks upon the sediments, without offering our views upon *Metamorphism.* Thus, rocks which are truly metamorphic are either connected with those of igneous origin, or erupted ones; or else, their relations are such that geologists are furnished with a clue to the cause or causes which were operative in effecting the changes which they have suffered. It is at the same time true, that changes, to a limited extent, have taken place without the instrumentality of a visible agent. It is often necessary in these cases, to refer them to a general principle or law, which has been frequently referred to in this work as a *molecular force.* It is under the influence of this force, that particles composing the sediments are rearranged; limestones, for example, pass into a crystalline condition, and the slates are cut up into tabular plates of a rhombic form, &c.,—a fact, which may

often be accounted for on the ground of great pressure and the influence of a molecular or crystalline force. Metamorphism is no doubt due to two principal causes: heat derived from the interior of the earth or the presence of eruptive rocks, and molecular force aided by the presence of water.

Water is probably always present in sediments, and to its presence is due in part, the mobility of their particles; indeed we have reason to believe that a mass may exist in a semi-plastic state, in consequence of which a re-arrangement of the particles will take place. Crystallization will then occur. Hence, many of the limestones are coarsely crystalline. Another class of rocks have been called metamorphic, which are scarcely entitled to the appellation. We refer to those into which talc and mica enter largely as constituents. In rocks thus constituted, we have no occasion to infer that the mica or talc has crystallized from the mass; it is rather to be inferred that they are simply derivative, and exist in the condition they originally were in the parent rock, excepting that their size has been diminished by attrition.

Fig. 57.



Paradoxides? quadrispinosus of the Taconic slates.

CHAPTER XI.

TACONIC SYSTEM—DIVIDED INTO UPPER AND LOWER—FOSSILS OF BOTH DIVISIONS.

113. THIS system* deserves the special attention of geologists for two reasons: 1st. It is probably the base of the *Sediments*; 2d. It is also probable, that it is the *Palæozoic base*, and, in both respects, it must be regarded as the oldest series of the sedimentary class. As mechanical sediments, they should, as a whole, bear more than any subsequently formed rocks, the aspect of the primary or pyro-crystalline ones; especially those beds which were first deposited. Such is the case: it is difficult to distinguish them from the rocks from which they were derived. This is particularly so with those members in which talc and mica are intermingled.

As the Palæozoic base, it is interesting from the indications the sediments furnish of the condition of the earth at the time when plants and animals were first created, and also the peculiar forms which peopled it in the dawn of their existence. At this period we have reason to assume, that the temperature of the earth was higher than it is now; but not to that degree as to be incompatible with the life of animals as they are now constituted. It is evident from the disturbances to which these rocks have been subjected, that the earth's surface was subject to great oscillations, and that chemical forces acted with considerable energy, probably greater than at any subsequent period.

This system has been called *metamorphic*, probably with more propriety than any other; yet there is scarcely in any case so much alteration or change in the masses composing it as to disguise

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* It is proper to state that several distinguished Geologists have regarded this system as the Lower Silurian; or as the equivalent of the Champlain group. According to their views the quartz rock of Berkshire is the Potsdam sandstone more or less altered by heat; the Stockbridge limestone is the Trenton limestone; and the slates crowning Graylock, the highest land in Massachusetts, are the Utica and Hudson River slates in an altered condition. This locality is the spot selected with a special reference to prove the foregoing doctrine.

their sedimentary origin. The lower limestones have lost, to the greatest extent, the peculiar phase which belongs to this class of rocks: The silicious rocks are often vitrified, or have lost their granular structure in a measure.

Regarding this period as one during which the mechanical and chemical forces were very energetic, we are, no doubt, furnished with a key to the solution of all the phenomena of this kind. At this period thermal springs were, no doubt, far more numerous than at present, and many of them held in solution large quantities of silex, which, when deposited, passed into the condition of vitrified masses, identical with the beds of chert and hornstone which is one of the common rocks of the system. It is by no means necessary to conceive a high degree of temperature common to the whole surface of the globe, but that the surface had so far cooled, that the water had accumulated in oceans and seas, and that waters of high temperature were merely local phenomena as now, being however more numerous and upon a larger scale.

The fossil vegetables, which belong to this series, are exclusively marine; in the upper part they are numerous.

114. The animals belong to three great divisions of the animal kingdom: Articulata, Mollusca, and Radiata. They represent the lowest forms of their respective types. Thus the articulata are represented by crustacea belonging mostly to the genus Paradoxides; the mollusca are either Brachiopodes, or those which are related to them, and very small; and the radiata are the lowest forms of Polypes, and are similar to the recent fungites.

The fossils of this system are, therefore, of the lowest rank; they are also rare. It has been maintained, that the rarity of fossils was due to the condition of the rocks; that, although they may have been as numerous as in the Lower Silurian series, yet, the rocks having been altered by heat, the organic remains were obliterated. But, unfortunately for this view, it is found that the parts of the series, which cannot be regarded as changed, are equally as barren as those which are located near the primary, and which are in the immediate region of metamorphic action. It is, therefore, probable that the paucity of organic remains, in this system, is due to the fact that it was not a period abounding in living beings.

While those which are found are interesting, because in the present state of our knowledge they are the first which appeared

upon the globe, they belong to *types* which are well known in our present seas, notwithstanding they are so far removed in time from the present. This confirms what we have maintained, that, in the almost innumerable forms of organic remains which belong to the different periods of the earth's history, none are known which do not belong to one of the four Cuvierian types, which are so fully represented in the living fauna of recent times. The unity of the plan of creation is most fully confirmed by facts which are drawn from this most ancient sedimentary epoch.

115. The distinguishing features of the rocks of this period must be obtained from the lithological characters of the rocks themselves, and from their relative position. They are conglomerates—brecciated conglomerates: sandstones, limestones, and slates, among which it is common to find cherty masses of considerable thickness intercalated. The important minerals which belong to this period are *gold, silver, specular oxide of iron*, hæmatites, and manganese; galena is sometimes found.

116. This system is subdivided into *Lower* and *Upper*; the first consists of a conglomerate at the base, succeeded by silicious talcose beds of considerable thickness, in which there are frequently pebbles; next above, are three thick beds of sandstone, separated by talcose slates; these are succeeded by the Stockbridge limestone. This is the marble of Berkshire county, Mass., and which extends from the state of Vermont to Georgia. The Stockbridge limestone is succeeded by a mass of slate of great thickness, the upper part of which is suitable for roofing. The greatest thickness of the Lower Taconic rocks is about 5000 feet. The upper quartz beds are often vitrified, while a lower one, still many hundred feet nearer the pyro-crystalline rocks, is a sandstone.

Fig. 58 illustrates the Berkshire masses. This section begins with the lowest beds resting on gneiss and granite, and extends across the summit of Oakhill in Williamstown, Mass., and west through the valley to the Petersburgh range.

1. Conglomerate at base. 2. Limestone. 3. Slate. 4. Conglomerates. 5. Slates. 6. Sparry Limestone. 7. Slates. C. Overlying Calciferous Sandstone. *f f f f*. Fractures.

The section fig. 59 is designed to illustrate the equivalent beds in Buncombe Co., N. C., near the Warm Springs. The conglomerates upon this section are much thicker than in Berkshire Co., and the lower Taconic is much more perfectly developed, and the quartz is much more vitrified. The materials composing the con-

glomerates in each section are derived from the pyro-crystalline rocks upon which they rest.

117. The Warm Spring Section, N. C., fig. 59, exhibits the following series:—

a. Gneiss. *b.* Sienitic Granite. 1. Talcose Slates with pebbles. 2. Seamy Brown Sandstone, more or less ferruginous. 3, 4, and 5. Slate with Pebbles. 6. Talcose Jointed Slates. 7, 7, 7. Talcose Slates. 8, 8. Granular quartz. 9. Gray Limestone.

Section fig. 60 is designed to show the position of the granular limestone of Berkshire Co., near Graylock, Williamstown, Mass. This rock crops out upon both sides of Saddle Mountain. 1. On the western slope facing the valley of Green river. 2. On the Adams side of the same range, and hence forms a low synclinal axis. Above the limestone, which is about 300 feet thick, is a thick mass of talcose slate; below it, is another very thick mass, lying between it and the granular quartz. Hence it will be perceived that these masses do not co-ordinate with the Lower Silurian or Cambrian. 1. Quartz. 2, 2. Limestone. 3, 3, 3. Slates above and beneath the limestone. C. Taconic range. B. Saddle Mountain. The foregoing sections represent the relations which these masses hold to each other throughout a continuous belt extending from Canada to Georgia.

The Lower Taconic series appears at Edgehill, Pa., where a whitish sandstone succeeds and overlies the gneiss. It is as usual interlaminated with slates, in which talc predominates. Limestone succeeds northward, but the series is soon concealed beneath the Permian and Trias. The Lower Taconic is also crossed by the Pottsville Railroad, near Norristown. This lower sandstone is usually underlaid by a conglomerate, but at neither of these crossings is this important mass present.

118. *Upper Taconic Rocks*, consist of numerous beds of slate alternating with shales, thin-bedded sandstone, some of which are coarse and brecciated, thin-bedded bluish limestone, more or less cherty and checked with seams of white calcareous spar, and red, brown, and purple roofing slates.

The following section extending from Comstock's landing on the Northern Canal, New York, to North Granville, shows the relation of the upper beds to the Lower Silurian. The description of the Silurian is in the ascending, and of the Upper Taconic in the descending order.

119. *a.* Gneiss: Comstock's landing. 1. Potsdam Sandstone. 2. Calciferous Sandstone. 3. Chazy Limestone. *a.* Slates interstratified with fine grits belonging to the Upper Taconic beds. *b.* Slates overlying a mass of chazy limestone.

Fig. 58.

Williamstown Section.

Fig. 59.

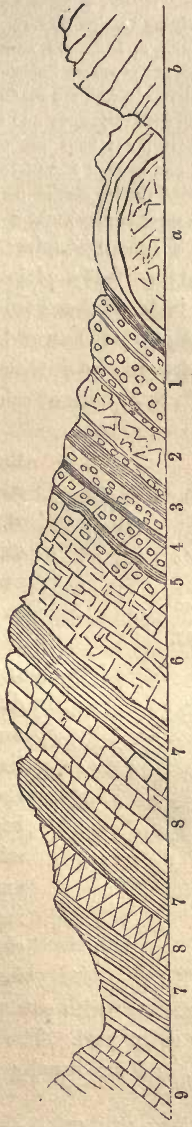


Fig. 60.

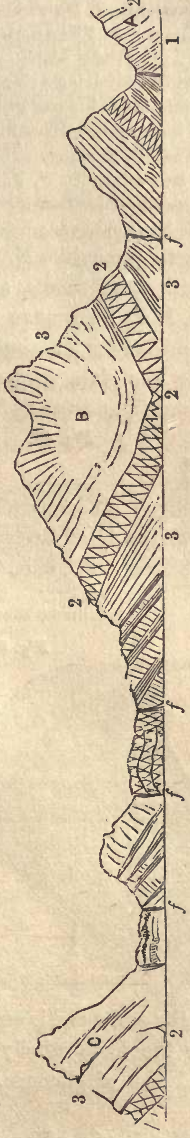
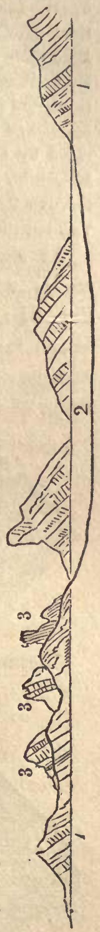


Fig. 61.



c. Thin Sandstones. *d.* Uneven-bedded Slates and Shales. *c.* Thin-bedded Sparry Limestone. *f.* Bluish Slaty Grits. *g.* Coarse Calcareous Sandstones. *i* Gray Sandstone. *k.* Flags containing marine plants. *l.* Cherty Sandstone. *m.* Blue Slates. *n.* Sparry Limestone. *o.* Blue, red, and purplish roofing slate of East Granville, containing a single bed of sparry limestone 3½ feet thick. *p.* Hard, thick and thin bedded coarse grits. *q.* Brick red roofing slate 200 feet thick. *r.* Slates and coarse grits alternating with sandstone and with brecciated beds separated by fine bluish slates. These lower beds are well exhibited in Grafton Mountain, Rensselaer Co., N. Y., and at Bird Mountain, Vt. The red slates pass through Granville Four Corners. A similar section may be traced in Wythe Co., Va., but the limestones are much more largely developed.

At North Granville, N. Y., the overlying Lower Silurian limestones with their fossils are perfectly plain at numerous points. Fig. 61 : 1, 1. Successive beds of the Taconic series. 2. Calciferous sandstone. The outlyers of Lower Silurian often occupy troughs in the slate, and frequently deceive the observer unless aware of the fact; as at 2, 3, 3, 3, beds of calciferous sandstone.

***Fig.* 62.**

Palæotrochis Minor.

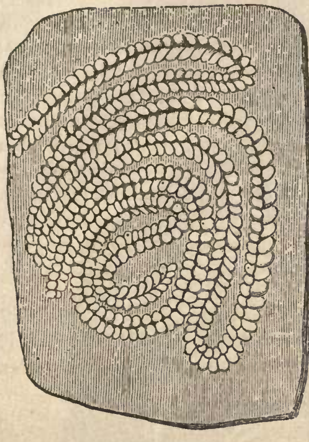
***Fig.* 63.**

Palæotrochis Major.

120. The fossils of the lower beds are limited to one or two species of corals, and, so far as discoveries have been made, these are confined to one region, though there are many localities; but the individuals are extremely numerous; these localities are in Montgomery Co., N. C.; and the beds are located about midway between the top and bottom of the quartz rock. The *Palæotrochis,* the name of the fossil in question, fills some of the strata and is associated with concretions, some of which envelope the fossil wholly or in part. The concretions take the form and size of almonds, and are usually formed of concentric layers.

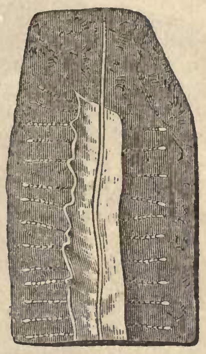
121. *Fossils of the Upper Series.*—They consist of marine plants, the lowest forms of animals, as graptolites, and several species of articulata, as trilobites and worm tracks.

Fig. 64.



Worm Tracks.

Fig. 65.



Diplograpsus ciliatus.
Enlarged.

Fig. 66.

Diplograpsus secalinus.

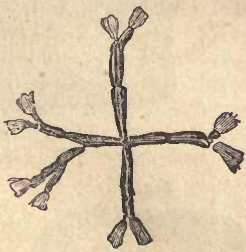
Fig. 67.

Diplograpsus rugosaus.

Fig. 68.

Diplograpsus Foliosus.
Enlarged.

Fig. 69.

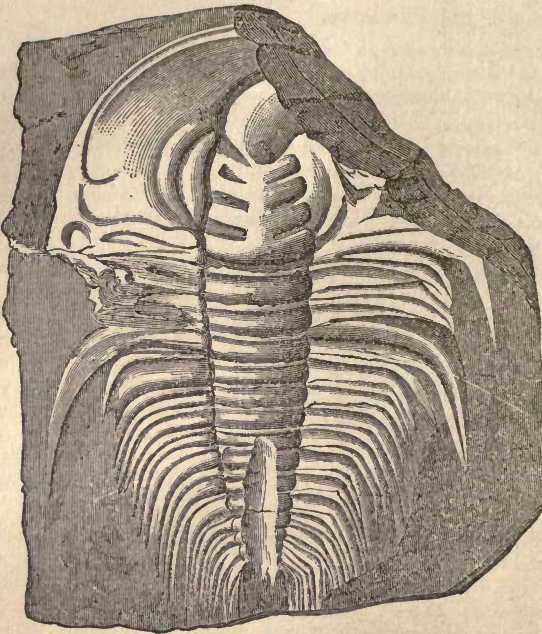


Staurograpsus dichotomus.
Enlarged.

Fig. 64. Worm tracks of the Waterville Slates (Nereites Deweyi). Fig. 65. Diplograpsus ciliatus. Fig. 66. Diplograpsus secalinus. Fig. 67. Diplograpsus rugosus. Fig. 68. Diplograpsus foliosus. Fig. 69. Staurograpsus dichotomus. Fig. 70. Paradoxides asaphoides. Fig. 71. Atops punctatus. Fig. 72. Obolus? Microdiscus quadricostatus (enlarged). Fig. 73. Fig. 74. Lingula striata. The two last are minute fossils.

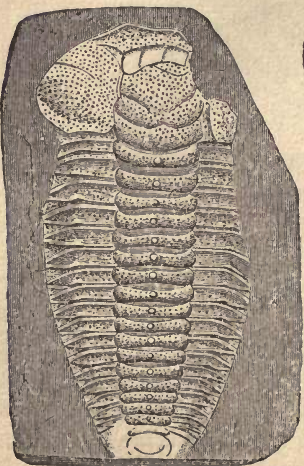
According to Barrande, the Paradoxides and Olenus belong to his primordial zone, or are Sub-silurian in Bohemia. In this respect our paradoxides are also Sub-silurian; and hence it has been shown

Fig. 70.



Paradoxides macrocephalus.

Fig. 71.

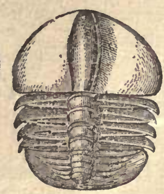


Atops punctatus.

Fig. 72.

Obolus.

Fig. 73.

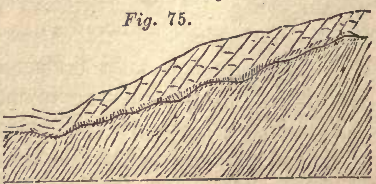


Microdiscus Quadricostatus. Enlarged.

Fig. 74.

Lingula Striata. Enlarged.

Fig. 75.



Unconformity of the calciferous sandstone *a*, with the Taconic slates, *b*.

that the primordial zone in Bohemia is in co-ordination with the upper series of the Taconic rocks.

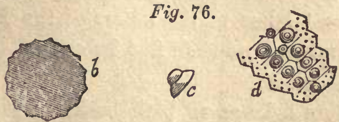
The range of country through which this series passes is the western face of the Green Mountains, extending from Canada to Georgia. These rocks cross the Blue Ridge at Harper's Ferry, or in its vicinity. They occupy also a range of hills or mountains, east of Wytheville, Va., extending westward to the immediate vicinity of the Queen's Knob, where they face unproductive coal measures. The series also passes along the eastern flanks of the Green Mountains and Blue Ridge, passing through the eastern part of Virginia and North Carolina, and onwards into Alabama. Upon this belt are numerous gold, copper, and iron mines in veins and beds.

The same series occur upon Lake Huron and Lake Superior district, and also in Arkansas in the vicinity of the hot springs. This series is developed on the Ocoee river in heavy beds of conglomerates, slates, and grits. Prof. Safford refers some of the rocks upon the French Broad in North Carolina and Tennessee, the rocks forming the ranges in Sevier County, to an Azoic or Sub-silurian system. Prof. H. D. Rogers distinctly defines a zone of sediments which he regards as semi-metamorphic, and which occupies a broad belt south of the limestone valleys of the Conestoga and Codorus streams in Lancaster and York counties. This zone, however, belongs to the Lower Taconic series, if his description can be relied upon. Prof. R. applies the term Azoic to these Sub-silurian deposits, a term which is inadmissible when applied to sediments.*

The Taconic series, especially the lower division, furnishes many fine exhibitions of displacements and inversions of strata. Of the latter, Stone Hill, an eminence south of Williams College, is an interesting example. The hill is about 500 feet above the Hoosick river. Its strata dip to the south-east; but the oldest layers repose upon the newest, so far as those composing the hill are concerned; or, in other words, they have been forced so far over that the original bottom beds occupy the uppermost position. Many contorted strata occur, exhibiting remarkable cases of lateral pressure.

* See Note A, page 280.

Fig. 76.



Echinus rufini (Eocene).

CHAPTER XII.

SILURIAN SYSTEM—GENERAL STATEMENT OF FACTS RELATIVE TO ITS EPOCH—DESCRIPTION AND DIVISION OF THE MEMBERS COMPOSING THE SYSTEM, ITS FOSSILS, ETC.

122. THE Silurian system, which fills so large a volume in the geologic history of Europe, seems to be still more full and complete in America. It extends from Canada on the north, to Alabama on the south. The Adirondacks, which bulge up, and form, as it were, a great but irregular dome, throw off the oldest sediments of the system in all directions, but more especially in two: one towards the north-east, and the other towards the south-west. The dip of the rocks, on the north-east side, indicates the existence of a great and widely spread-out basin in this direction, which might be called the *Lawrentine Basin* of the system. Following the dip to the south-west, the indications are equally clear that, in this direction, too, there is another basin of a vast extent having its south-eastern base in the Appalachian Mountains, and, hence, might be called the Appalachian Basin of the Silurian system. These basins are separated by an anticlinal axis, which is very clearly marked by the Highlands of Northern New York. A rough measurement through both basins, over this anticlinal, gives us at least a distance of twenty degrees of latitude. Following the base of this system from the northern extremity of Lake Champlain to the St. Lawrence, and then tracing its course along the irregular borders of the great lakes to the waters of the Mississippi above the Falls of St. Anthony, we shall find its extent, in this direction, not less than 1500 miles.

A peculiar feature belongs to both basins, especially the south-western one. It consists in the remarkable regularity of the succession of its strata. These wide areas are scarcely broken by igneous injections; and, hence, the regular succession of strata is rarely interrupted or displaced by outbursts of the pyro-crystalline rocks.

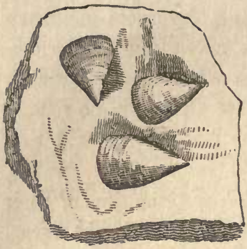
This freedom from breaks and interpolated igneous masses had

an important bearing upon the regularity of the succession of its organic stages; and, hence, secured the most favorable condition for the preservation of life; and to this we may attribute the perfect representation of these stages during the whole Silurian period. The two facts seem to harmonize so well that they may be related to each other as cause and effect. From the foregoing it will probably follow, that the time, when important species were created, may be more exactly determined; and so, also, may the time of their extinction become a matter more easily settled, than if the areas, over which they are spread, were broken and dislocated by frequent eruptions. The history of the Palæozoic period will, therefore, be more complete, and at the same time more interesting for its manifold developments of organic beings. It is in this system that life begins to assume a supremacy over dead matter. All the great branches representing animal life appear in this period, though not in perfection. It is mainly the lower ranks of each branch respectively, which appear in this system. It might be called the Prophetic system.

It is all important that the student should be informed, that, with respect to American systems of rocks, we have, as yet, been unable to make out that their subordinate parts have, in all instances, their synchronisms in the European systems of the same name. We can identify certain subdivisions; but there are many breaks between the subdivisions, which have not as yet been shown to be synchronous. It will be well to prove, if possible, that our formations are parallel with well-known European ones; but nothing is gained by *assuming* it to be the fact in the absence of proof. The American continent has its own history; and we have reason to believe that, in many respects, especially in its details, we shall find it to differ from that of Europe. Hence, it should be worked out independently of foreign bias. It is, no doubt, true, that, as great masses, there is a close connection in the American and European divisions; and, in many instances, it exists in the subordinate parts, and some of the breaks are synchronous; others are not yet proved to be so.

123. *Subdivisions of the Silurian System.*—The Silurian system may be divided into *Lower*, *Middle*, and *Upper*: *Lower Silurian, Champlain Group*, or *Cambrian.* The oldest member of this division is a sandstone of a red, gray, or chocolate color, and sometimes white. It is the Potsdam sandstone of the New York survey. The

Fig. 77.



Lingula antiqua.

bottom is a conglomerate. Its greatest thickness is about 300 feet. It contains a lingula, fig. 77, and two or more species of trilobites. The next in succession is the *Calciferous Sandstone*, being a mixture of carbonate of lime and fine grains of quartz. In color it varies, but usually is of some shade of gray. Weathers to a drab color. It is sometimes oolitic, as at Chazy, or concretionary, as at Little Falls. Its fracture is uneven and sparkling. The middle and upper parts are cherty, and contain much magnesia, and has been called magnesian limestone; it contains quartz crystals and solidified bitumen; the latter is often enclosed in limpid quartz. Fig. 78 represents some of the fossils of this rock. In the absence of the Potsdam sandstone, as at Little Falls, N. Y., it rests upon the pyro-crystalline rocks or the Taconic system. It is more extensive than the former rock. At Chazy, N. Y., it is highly fossiliferous.

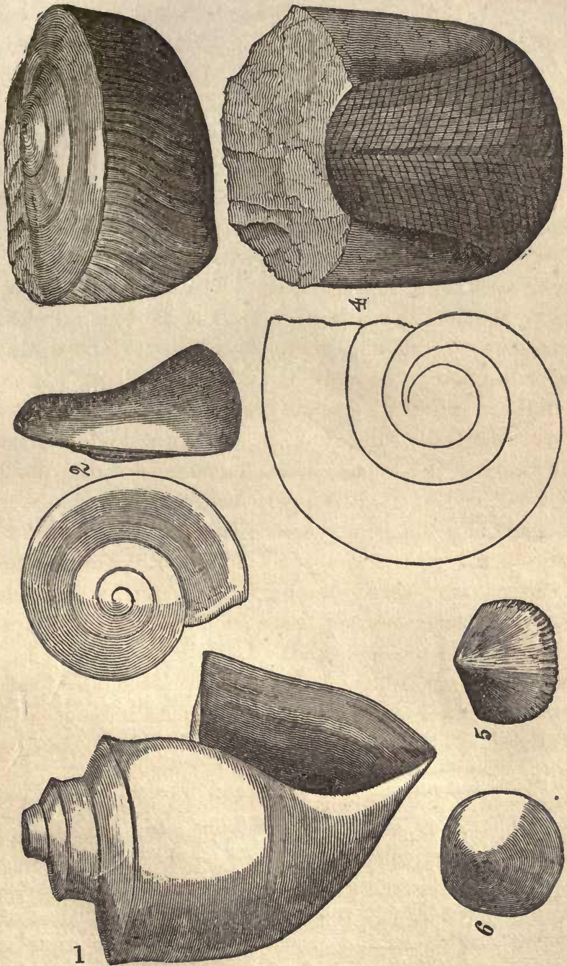
124. The Chazy limestone succeeds the calciferous sandstone. It is a dark-colored rock, and abounds in corals. But its most important organic remains are gasteropods, particularly the Macleurea, fig. 79. This name, however, has been changed into Straparollus by D'Orbigny. It was first called Maclurites magnus by Le Seur We have followed D'Orbigny, and hence this remarkable fossil takes the name of Straparollus magnus. It is quite common at Chazy and at Essex, N. Y. It is equally common in the same rock in Wythe Co., Va.

A coral is also quite common: the Columnaria alveolata, Fig. 80.

The Birds' Eye Limestone, which overlies the Chazy, is a close-grained, compact limestone, and breaks with a conchoidal fracture; it is rarely, if ever, over 30 feet thick. In Canada its color is quite light, and it has been used for lithographic drawings. The fossils of the Trenton appear in the rock. A very singular fossil, called by Mr. Conrad Fucoides demissus, fig. 81, seems to characterize the limestone. Its name has been changed to Phytopsis tubulosum by Hall. Several cephalopods occur in this rock: the most common is the Orthoceras multicameratum, fig. 82.

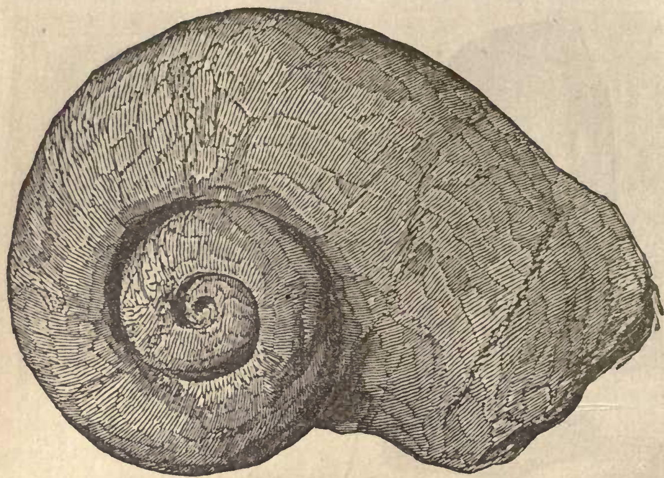
The Bird's Eye is a very compact and brittle rock, and breaks with a conchoidal fracture. It presents numerous crystalline

Fig. 78.



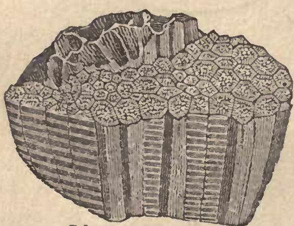
1. Scalites angulatus. 2. Straparollus labiatus. 3. Straparollus striatus. 4. Bellerophon sulcatinus. 5. Cast of orthis. 6. Discina.

Fig. 79.



Straparollus magnus.

Fig. 80.



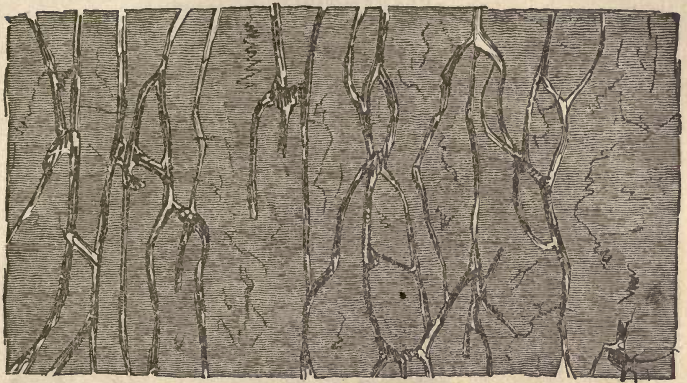
Columnaria alveolata.

points, which gives the surface the peculiar appearance from which its name was derived.

The Black River limestone, or Isle La Motte marble, is the least common; but, at Watertown, N. Y., and Isle La Motte, on Lake Champlain, it is present. It is black, and is extremely fine-grained. It is between seven and fifteen feet thick, and it forms a fine black marble.

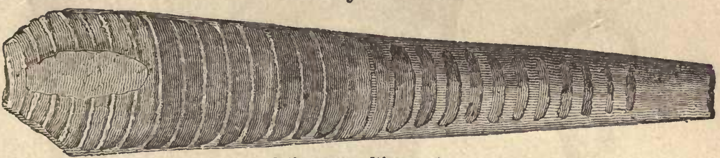
125. The Trenton limestone is either black or gray. The lower part is usually black, and when well developed, as at Watertown, N. Y., it becomes gray and sub-crystalline. These divisions of this limestone were made on the ground that each mass contains peculiar fossils, and which are confined to each respectively. This is found untrue. The thickness of the Trenton limestone is about 400 feet. The total thickness of the four masses of limestone, as given by Mr. Logan, near Montreal, is 1200 feet, but at the Manitoulin Islands, or westward, they diminish in thickness, and scarcely exceed 300 feet. The Trenton limestone is variable as to its lithological character. At certain localities, as at Chazy and

Fig. 81.



Phytopsis tubulosum.

Fig. 82.



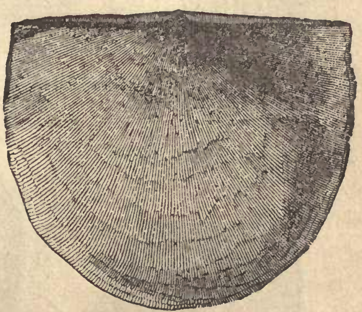
Orthoceras multicamerata.

Montreal, it has intercalated beds of black bituminous slate. At other places it is mainly a solid limestone.

126. The fossils are abundant in all these rocks, especially the Trenton limestone. Some of the characteristic forms are represented in the following cuts.

Fig. 83.
Ventral valve.

Fig. 84.
Dorsal valve.



Strophomena alternistriata.

Fig. 85.

CEPHALOPODA.

1

Cyrtoceras megastoma.

2

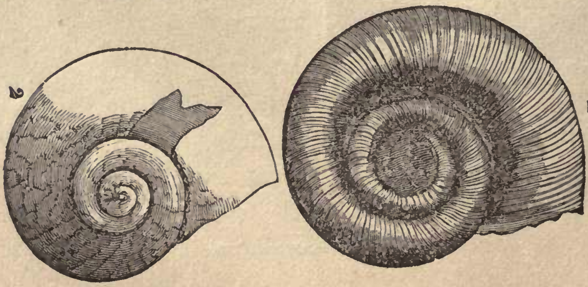
Endoceras proteiforme.

Cyrtolites compressus.

Mouth of the Trocholites.

Gonioceras halli.

2 1



Trocholites ammonius.

Fig. 86.

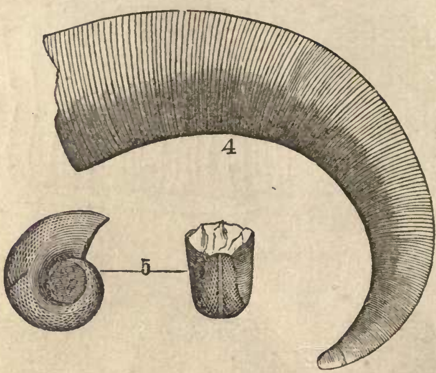
CEPHALOPODA.

Lituites undatus.
Side and Back Views.

Fig. 87.

GASTEROPODA.

Subulites (Loxonema) elongata Con.

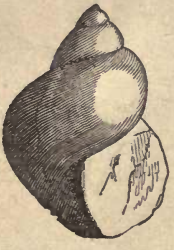


4. Cyrtolites filosum.
5. Bellerophon punctifrons.

Murchisonia abbreviata.

Turbo ?

Calymene senaria.



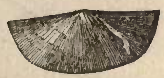
Turbo obliquus.

Bellerophon bilobatus.

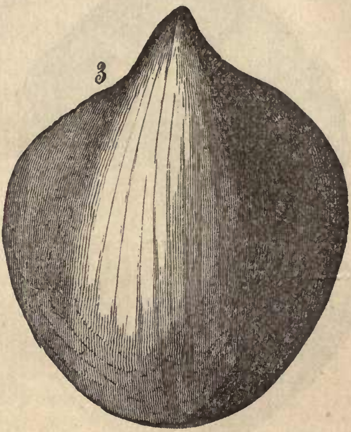
Pleurotomaria lenticularis.

Fig. 88.

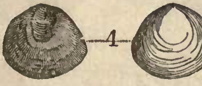
BRACHIOPODA OF THE TRENTON LIMESTONE.



4a. Surface of T. terminalis. Leptæna sericea.

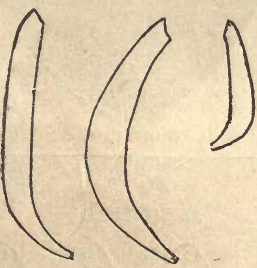


Ambonychia orbicularis.

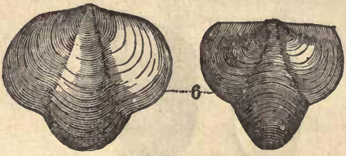


Trematis terminalis.

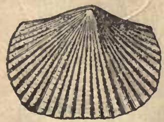
Lingula papillosa. Discina truncata.



Sections of the Strophomena.



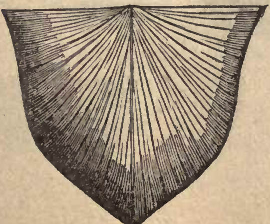
Triplesia extans.



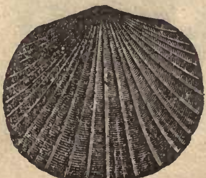
Orthis pectinella.

Orthis testudinaria.

Strophomena sinuata.



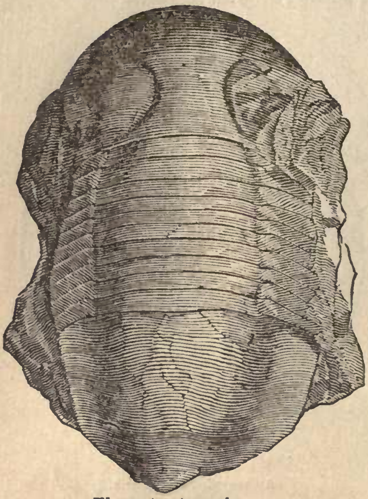
Strophomena alternata.



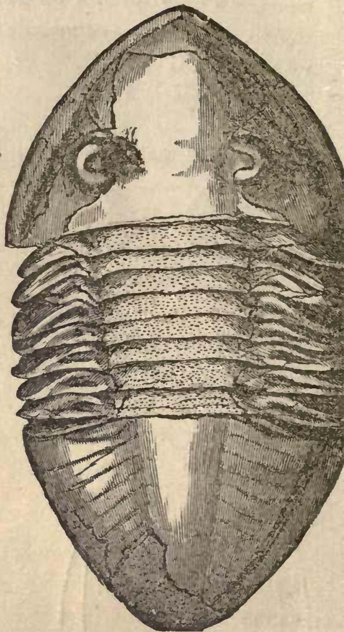
Orthis pectinella.

Fig. 89.

CRUSTACEA.



Illænus trentonensis.



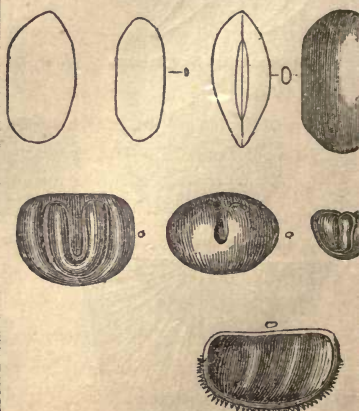
Isotelus gigas.

Illænus crassicauda.

Triarthrus Beckii.

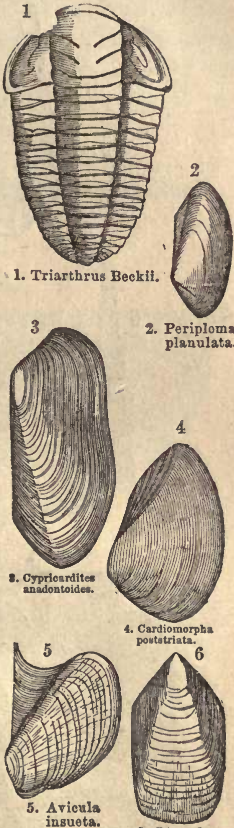
Fig. 90.

AGNOSTIDES.



The Utica slate, which is a black and tender rock, reposes upon the Trenton limestone. It is often bituminous. Its greatest thickness is about 75 feet. It does not occur in a condition of a roofing slate. To this slate the Lorrain shales and sandstone succeed. The line of junction is obscure, and the annexed fossils occur in both series of beds. These are thin-bedded shaly deposits with a few calcareous beds interposed. 'The lowest beds are quite thin, and alternate with slate. As we ascend in the series, the silicious or sandy beds become thicker, and the formation finally terminates in a thick-bedded gray sandstone in New York and Canada. In the West, or in the vicinity of Cincinnati, the whole formation is much more calcareous, and is there known as the *Blue Limestone.* It is fossiliferous, especially in the West.

Fig. 91.
FOSSILS OF UTICA SLATE.



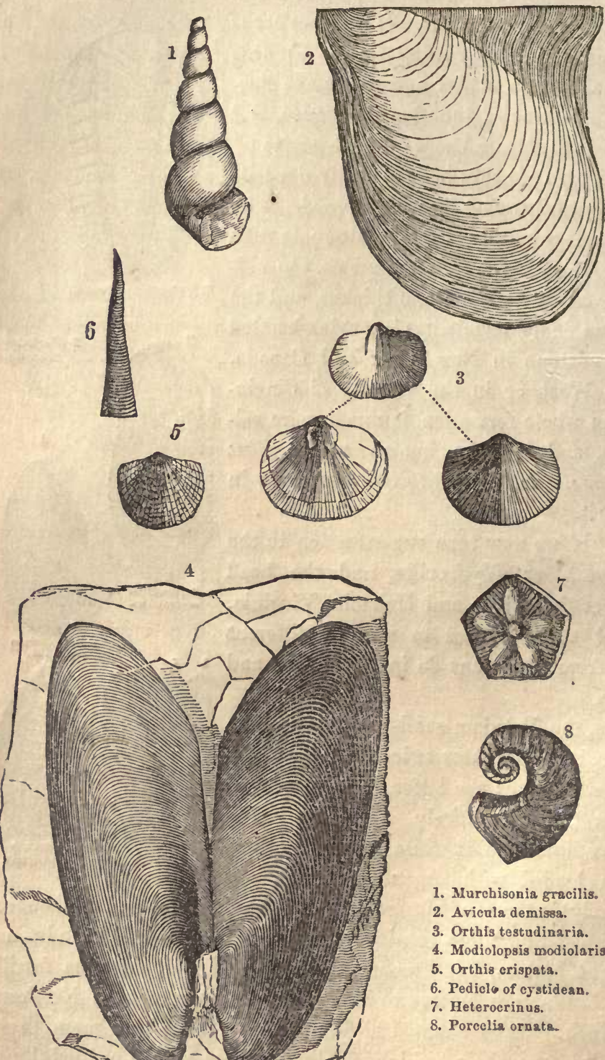
1. Triarthrus Beckii.
2. Periploma planulata.
3. Cypricardites anadontoides.
4. Cardiomorpha poststriata.
5. Avicula insueta.
6. Lingula quadrata.

127. If we now turn our attention to the south-west, or Wytheville, and the head waters of the Clinch and Holstein, Virginia, we find these masses to wear a different phase from what they do in New York and Canada.

Thus, the Potsdam sandstone has an open texture, and alternates twice with the Calciferous sandstone; the latter, in many places, consists almost entirely of chert. The Trenton limestone is white and crystalline, though loaded with organic remains, and is entirely destitute of bitumen. The Lorrain shales and sandstones, in the ascending order, consist of, first, a reddish, mottled sandstone, pebbly at bottom, but becomes a sandy marl, and contains fossiliferous bands, which serve to identify it with the rock in Northern New York. It is about 100 feet thick. Above this mass there is a calcareous shale, which finally becomes a thin-bedded limestone, and, still higher, there are olive-green, thin-bedded sandstones and marls, containing Pterinea carinata. These beds are equivalent to the thick-bedded sandstones of Oneida, Jefferson

Fig. 92.

FOSSILS OF THE LORRAIN SHALES.

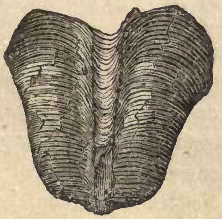


1. Murchisonia gracilis.
2. Avicula demissa.
3. Orthis testudinaria.
4. Modiolopsis modiolaris.
5. Orthis crispata.
6. Pedicle of cystidean.
7. Heterocrinus.
8. Porcelia ornata.

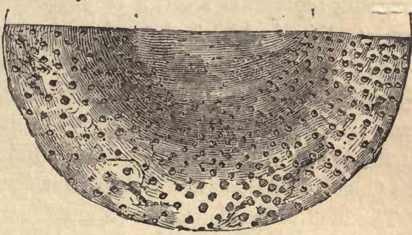
county, New York, and the Blue limestone in part of the Western States.

128. *Oneida Conglomerate.*—Above, and resting upon the last member of the foregoing series, is the Oneida conglomerate, or Shawangunk grits. It is a hard gray rock made principally of pebbles. Whether it should be considered as holding a connection with the foregoing rocks, or be regarded as the inferior member of the Middle Silurian, is not well determined. In one point of view, it is an important rock, insomuch as it indicates a line of demarkation between the Lower and Middle Silurian rocks. It is probable, that it belongs to the Middle Silurian.

Fig. 93.

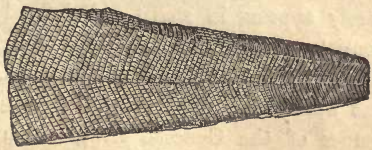


Bellerophon rugosus. Enlarged.



Receptaculites circularis. Enlarged.

Trinucleus Caractaci?



Conularia Hudsonia. Enlarged.

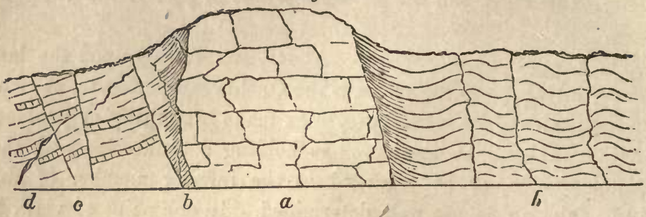
Receptaculites belongs to the sub-class *Bryozoa,* and appears to be a rare fossil. The Conularia belongs to the class Pteropoda, and is also a rare species in the Lorrain shales.

The Lower Silurian, in Northern New York, is rarely disturbed by dykes or intruded rocks. In Jefferson and St. Lawrence counties, the Potsdam Sandstone is tilted up, and the specular oxide of iron, in those cases, often occupies a position between the Potsdam and the primary rocks beneath.

On the Champlain side near the village of Essex, and, indeed, in many other places, trap-dykes and porphyritic rocks cut through the lower limestones.

Near Essex, the Calciferous sandstone is raised upward, so as to

Fig. 94.



Disturbed Strata in the Lower Silurian, Essex Co., N. Y.

be on a level with the Utica slate, as represented in Fig. 94. *a*, calciferous sandstone; *d*, line of junction with the slate; *c*, thin dykes traversing the slate; *b*, slate thrown into undulations. The foregoing represents a series of phenomena which are common in districts disturbed by faults and igneous injections.

129. *Middle Series of the Silurian or Ontario Division of the System.*—It comprehends the Oneida Conglomerate or Shawangunk Grits, the Medina Sandstone, Clinton, and Niagara Groups. In the West, this division is called Cliff Limestone, not including the Oneida Conglomerate and Medina Sandstone.

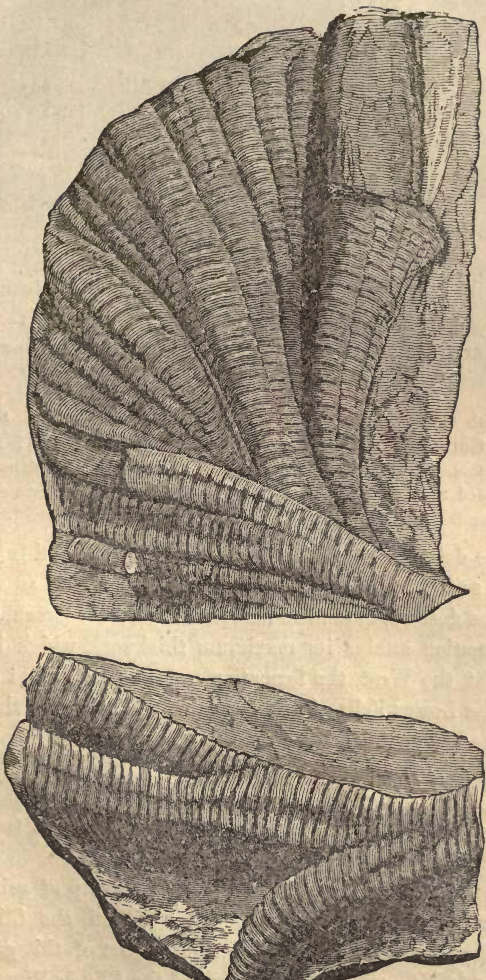
The Medina Sandstone is an argillaceous mottled sandstone, in part, and is easily destructible by atmospheric agencies; hence, it rarely appears in sharp well-defined outcrops. The upper part consists of firm and thin beds of light-reddish sandstone, with a texture sufficiently close to preserve, in perfection, ripple marks and wave lines. There is also a coarse gray band at the top in the gorges of the Genesee river, which is somewhat pebbly. The rock is also mottled with light-green patches like the New Red or Triassic Sandstone. It is the lowest rock which is known to furnish brine-springs. They are not, however, pure enough, nor do they furnish saline matter in sufficient abundance, to be employed economically in the manufacture of salt.

It forms a border along the shore of Lake Ontario and the crests of the Alleghenies in Virginia.

Fossils of the Medina Sandstone: The most common fossil is the Arthopycus Harlani, fig. 95, a marine vegetable, and formerly described as the Fucoides Harlani. It is common to New York and the Virginia series. The Lingula cuneata (Fig. 96) is also a common fossil.

130. *Clinton Group.*—It consists of many beds comprising gray and brown sandstones, green shale, slate, conglomerates, limestones,

Fig. 95.



Arthopycus harlani.

Fig. 96.

Lingula cuneata.

and oolitic iron ore. It has been called the Protean Group on account of the heterogeneous assemblage of materials.

In Warren, Herkimer County, New York, the following section occurs:

1. Bluish Gritty Shale, 1 foot. 2. Gray Sandstone, 2 feet. 3. Blue Gritty Shale, 1 foot. 4. Gray Sandstone, 4 feet. 5. Pebbly Beds, 2 feet. 6. Blue Shale, ½ foot. 7. Grayish Shale, ½ foot. 8. Iron Gray Sandstone, ½ foot. 9. Thin-bedded Sandstone, 1 foot. 10. Fine Pebbly Conglomerates, 8 feet. 11. Soft Brown Sandstone, 2 feet. 12. Dark-colored Shale, 3 feet.

In the debris are fragments of iron ore. The bed is concealed.

This series rests on the Oneida Conglomerate, as the Medina sandstone does not extend so far east. On Steel's Creek, at Mohawk, the formation attains its maximum thickness, which is about 70 feet. At the West, the formation presents a different aspect.

At the Lower Falls of the Genesee, reckoning in the ascending order, we have obtained the following section:

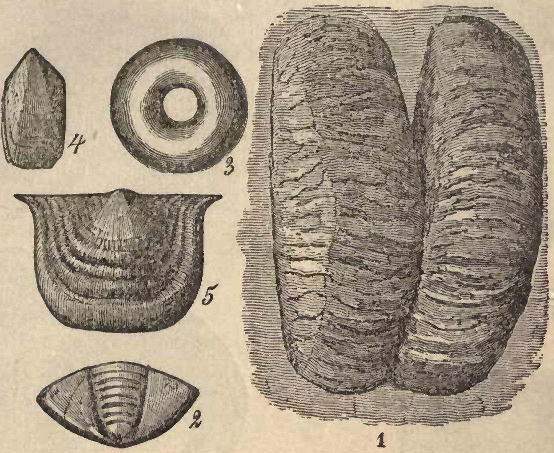
1. Gray Band of the Medina Sandstone. 2. A Tender Fissile Green Slate.—15 feet. 3. Lower Bed of Oolitic Iron Ore.—14 inches. 4. Limestone with Pentamerus oblongus.—14 feet. 5. Green Shale, like No. 2.—24 feet. 6. Impure Limestone and Shale.—18 feet.

To the east, this group is sandy, or made up of grits, while to the west it becomes calcareous. At Anticosti, the Clinton group is well-developed, or the rocks consist in part of this group.

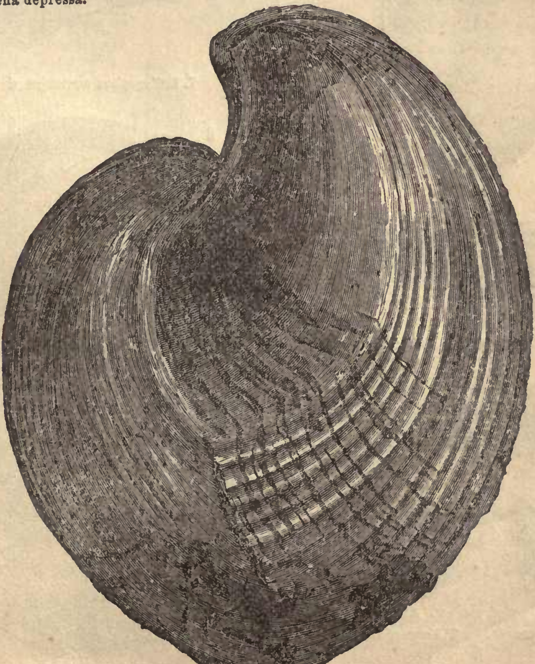
Walker's Mt., on the head waters of the Clinch River, in South-Western Virginia, and the subordinate ranges of this region, are composed of the rocks of this group. The Medina sandstone often forms their summits.

Fig. 97.

FOSSILS OF THE CLINTON GROUP.

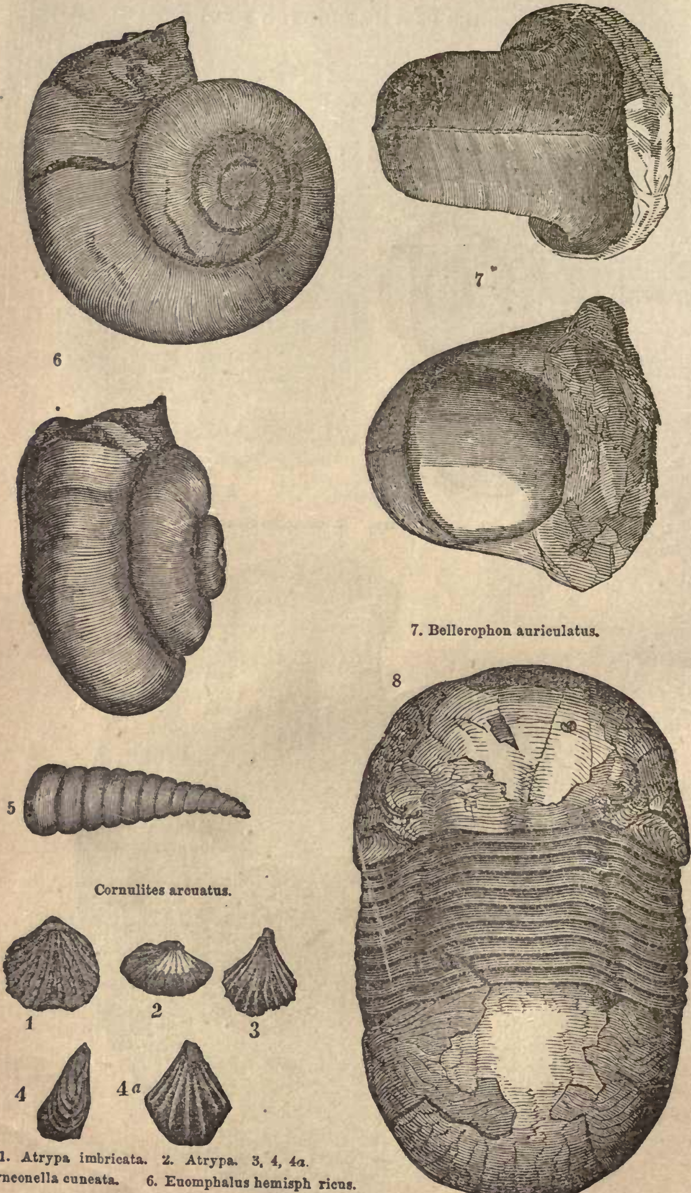


1. Rusophycus bilobatus. 2. Hemicripturus. 3. Crinoidal Joint. 4. Lingula oblonga. 5. Strophomena depressa.



Pentamerus nobilis, E.

Fig. 98.



7. Bellerophon auriculatus.

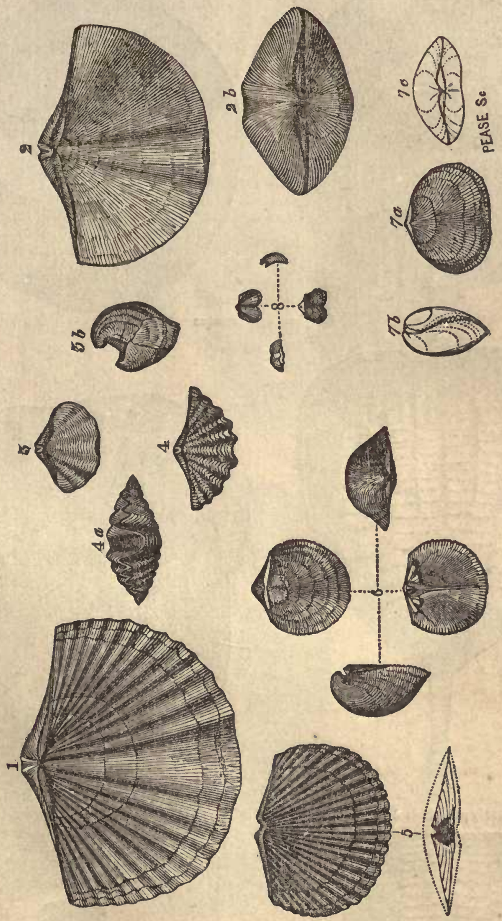
Cornulites arcuatus.

1. Atrypa imbricata. 2. Atrypa. 3, 4, 4a. Rhyneconella cuneata. 6. Euomphalus hemisph ricus.

8. Illænus barriensis.

Fig. 99.

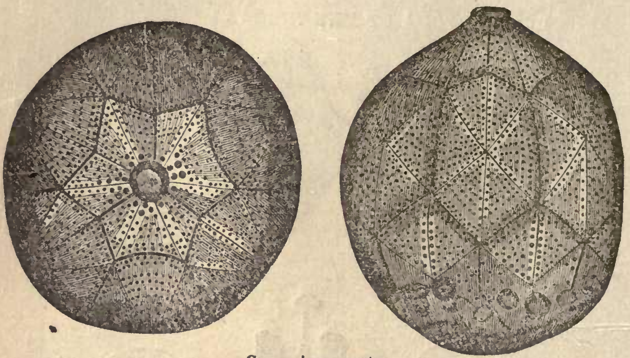
BRACHIOPODA OF THE NIAGARA GROUP.



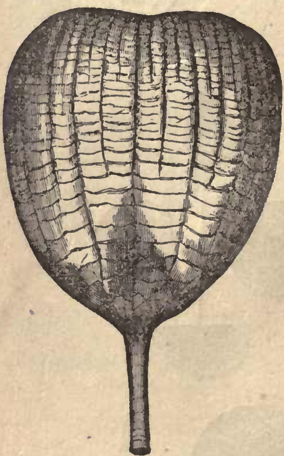
1. Spirifer Niagarensis. 2. Spirifer radiatus. 3. Spirifer staminea. 4. Spirifer decemplicatus. 5. Orthis flabellum. 6. Orthis canalis. 7. Orthis hybrida. 8. Spirifer sinuatus.

Fig. 100.

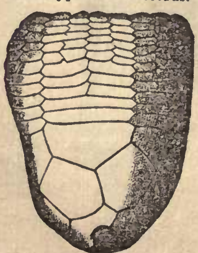
CRINOIDS OF THE NIAGARA GROUP.



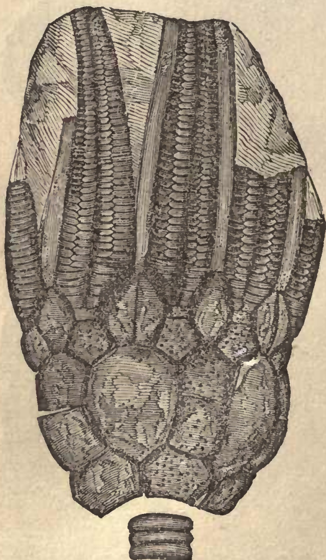
Caryocrinus ornatus.



Eucalyptocrinus decorus.



Lecanocrinus macropetalus.



Ichthyocrinus lævis.

Fig. 101.

CORALS OF THE NIAGARA GROUP.

1, 2, 3. Halycites catenularia.

The Halycites (Catenipora) catenularia is probably never found above or below the Clinton and Niagara groups, and is hence a very characteristic fossil.

Niagara Group.—It consists mainly of three members: Niagara shale, Niagara limestone, and Coralline limestone. The first is a tender, bluish rock, which whitens on exposure to the weather. The second is often a dark-colored massive limestone, and frequently bituminous. It may be described in the following section:—

1. Beds of gray silicious limestone, often hydraulic.
2. Thin beds of shaly limestone, sometimes concretionary.
3. Thick and thin beds of limestone.
4. A cherty and bituminous limestone; gray or brown, with numerous geodes of calcspar, gypsum, strontian, or brown spar.

The limestone is often crystalline and sparkling, as at Lockport.

The eastern limit of this limestone is Swift Creek in Oneida Co., where it is curiously concretionary, and only about four feet thick.

Thickness of the Ontario Division in New York.

The Medina Sandstone is	350	feet thick.
Clinton Group	80	"
Niagara Shale	100	"
Niagara Limestone	160	"
	690	

131. *The Coralline Limestone,* in the Helderberg, rests on green shale, which is, no doubt, the representative of the Clinton group. It is scarcely probable the equivalent of the Niagara limestone, as the rock contains fossils similar to those which characterize the succeeding masses.

132. *General Distribution.*—The Ontario division is quite extensive in the United States. In New York it forms a narrow belt along the south shore of Lake Ontario. It dips south or south-west. In Pennsylvania it occupies a narrow belt along the north-western base of the Kittatinny Mountain. It extends from Perry county, nearly to the Delaware Water Gap. The Medina sandstone, accompanied by the Clinton group, with its iron ores, form the summits or belts of all the ridges west-south-west of Wytheville, Virginia. The top of Walker's Mountain, about twelve miles from Wytheville, is probably carboniferous; but, immediately beneath, the Medina sandstone, becomes a very prominent rock, and caps the ridge on Shannon's side of this mountain. In a descending order, we find the following succession:—

1. Clinton group, and an imperfectly developed Niagara limestone, which is very cherty. 2. Medina sandstone. 3. Upper Lorrain shalo, slates, and sandstones. 4. Calcareous beds. 5. Lower Lorrain beds, consisting of green shale, brick red massive slates, and very tough; gray sandstones and conglomerate. 6. White Trenton limestone. 7. Bird's Eye and Chazy limestone. 8. Calciferous sandstone with drab-colored layers. 9. Gray sandstone (Potsdam). This division of the Silurian occupies, therefore, the summits or ridges of the high ranges about the head waters of the Clinch and Holstein.

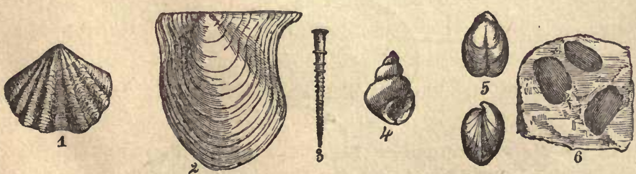
133. *Helderberg, or Upper Division of the Silurian System.*—In this series we place the Onondaga salt and plaster group. The Manlius Water limestone, Pentamerus limestone, green shaly limestone, Encrinal limestone, and Upper Pentamerus limestone.

134. *The Onondaga Salt Group* consists of soft, red, and mottled argillaceous shales, which, at many places, pass into a drab color. The lower part is a bluish marl, with bands of red and brown; above, it becomes calcareous, and contains seams of gypsum, and at its termination in Onondaga Co., it becomes gray or drab-colored limestone, which is magnesian. The contrast between this great deposit of soft shales and marls is very great, when compared with the Niagara limestone on which it rests. The softer portions contain hopper form cavities, or moulds which appear to have contained crystallized rock salt.

135. *Extent.*—Westward it extends into Canada: an obscure mass of rock, about 20 feet thick, in the Helderberg and at Schoharie, represent the whole formation. It is not generally distributed, and should be regarded rather as a local, though by no means an unimportant formation. It furnishes from its middle beds a large quantity of plaster, and from the wells, which are usually sunk in drift, brine springs, which give a large revenue to the state of New York.

Fig. 102.

WATER LIME FOSSILS.



1. Spirifer plicatus. 2. Avicula rugosa. 3. Tentaculites ornatus. 4. Holopea antiqua. 5. Atrypa sulcata. 6. Leperditia alta.

136. *Water Lime, or Manlius Water Lime Group.*—It consists of thin-bedded drab, or gray limestones. The upper beds are thick, and are employed for the cement so well known in market.

The Pentamerus limestone succeeds, and it is almost always concretionary, at least in part. It is gray and thick-bedded.

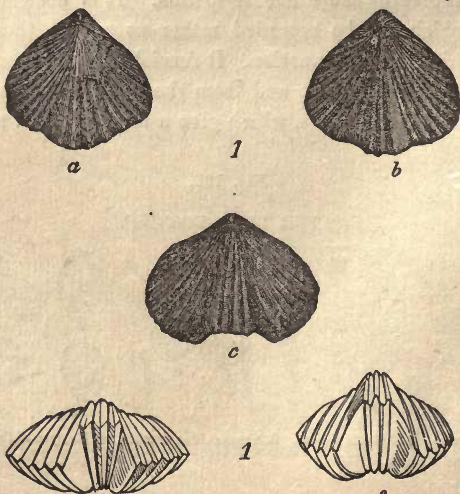
Both the foregoing masses are well developed at the base of the Helderberg, and also in the valley of the Rondout, and Becraft's Mountain, east of Hudson.

Green shaly limestone is an argillaceous limestone, and many of its layers are very thin: rarely crystalline. It weathers from a bluish color to a drab. It may be examined at Becraft's Mountain, and on a line of outcrop from Kingston Point to Coeymans at the Helderberg, Schoharie, and west a short distance beyond Cherry Valley in New York. It is about thirty feet thick. It is remarkably rich in fossils, but is not widely distributed.

137. *Encrinal Limestone.*—It is a semi-crystalline rock, and is made up in great measure of peculiar crinoidal remains. It is nearly a pure limestone, and polishes well, and hence it often furnishes fine slabs for mantel-pieces, tables, &c. It is 25 feet thick at Becraft's Mountain, and but scarcely exceeds 10 at New Scotland in the Helderberg.

Fig. 103.

BRACHIOPODA OF THE UPPER SILURIAN.

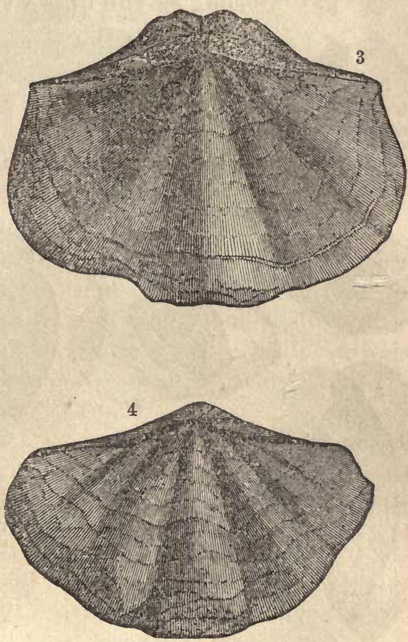


Rhyconella formosa.

a, *b*. Dorsal view. *c*. Ventral view. *d*, *e*. Edge view

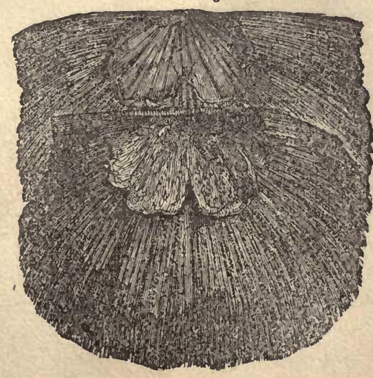
Fig. 104.

BRACHIOPODA OF THE UPPER SILURIAN.



3, 4. **Spirifer macroptera.**

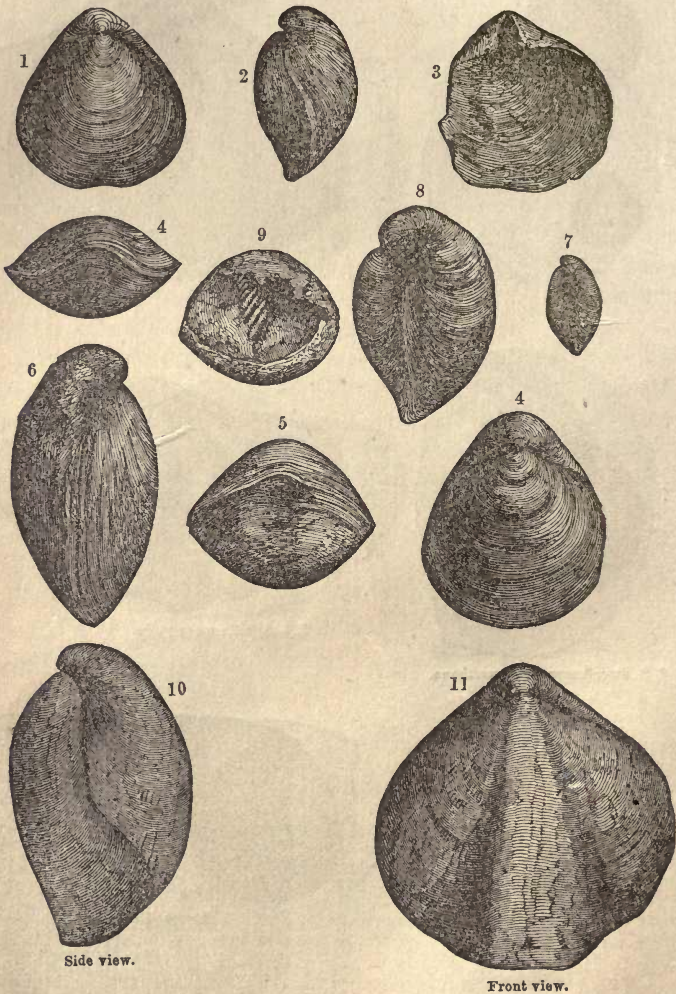
1, 2. **Strophomena Woolworthana.**



Strophomena Headleyana.

Fig. 105.

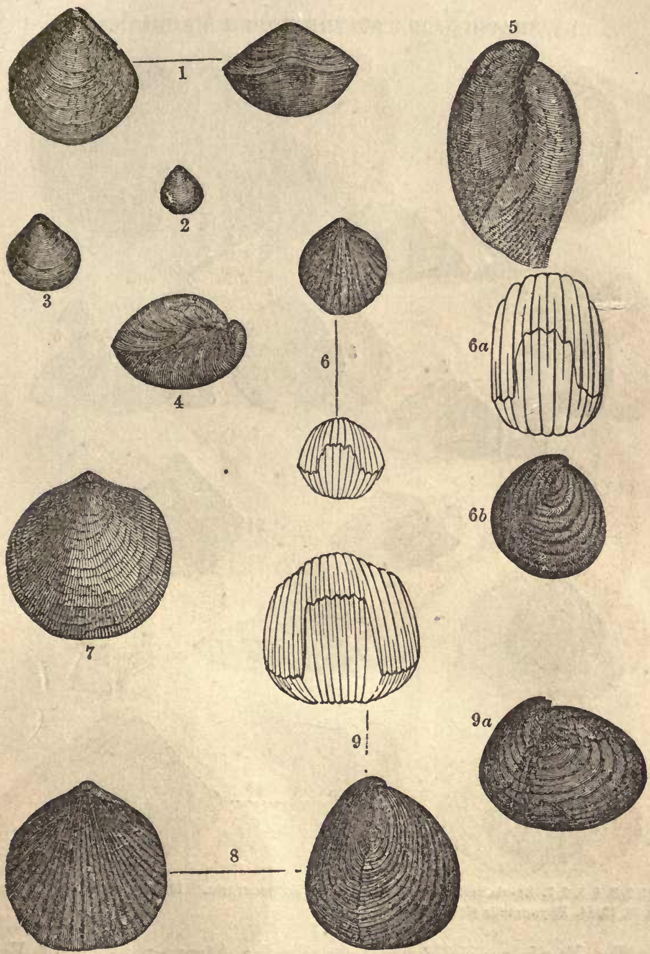
BRACHIOPODA OF THE GREEN SHALY LIMESTONE.



1, 2, 3, 4. Merista arcuata. 4, 5, 6, 7, 8, 9. Merista lævis. 10, 11. Merista princeps.

Fig. 106.

BRACHIOPODA OF THE UPPER SILURIAN.

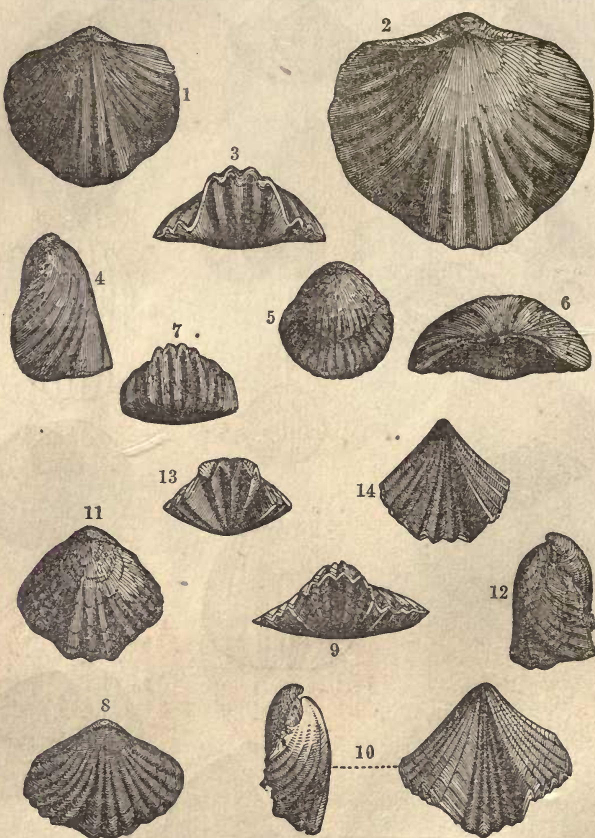


1, 2, 3, 4. Meristabella. 5. Merista princeps. 6, 6 *a*, 6 *b*. Rhynconella mutabilis. 7. Orthis. 8, 9, Rhynconella mutabilis. 9 *a*. Rhynconella ventricosa.

The genus Merista is closely allied to the Terebratula: its beak is imperforate. Their shells are ovate, sometimes transversely so, and are ornamented by parallel circular lines. The mesial fold is much less prominent than in the Rhynconella. The shell is thin, often ventricose. The beak is rather prominent and incurved.

Fig. 107.

BRACHIOPODA OF THE UPPER SILURIAN.

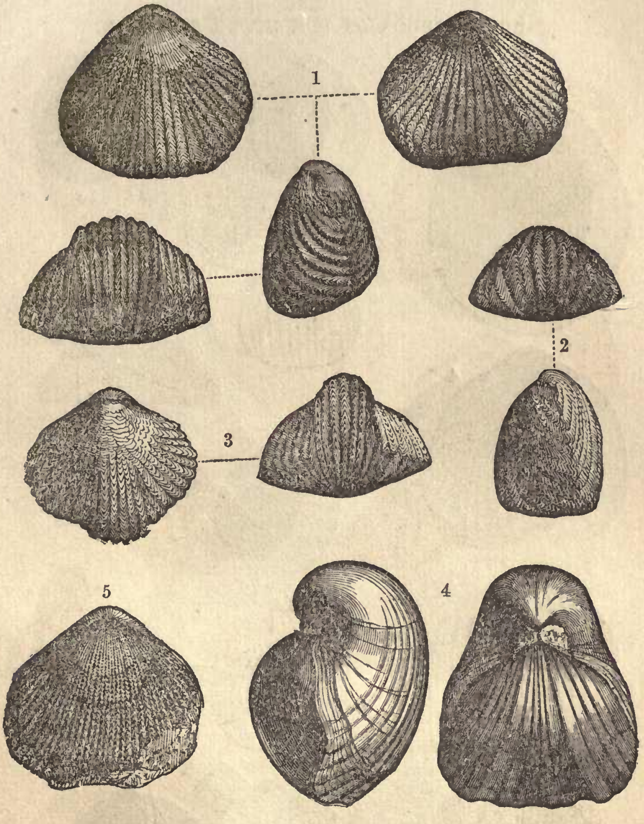


1, 2, 3, 4, 5, 6, 7. Etonia medialis. 8, 9. Rhynconella transversa. 10. Rhynconella acutiplicata. 11, 12, 13, 14. Rhynconella altiplicata.

The Etonia medialis was formerly the Atrypa medialis of Vanuxem, figured in the New York Geological Reports. The internal structure of the fossil is found to differ from the genus Atrypa; and hence the necessity of changing the name of the fossil. The ventral valve is also flat, and the hinge is indicated by a straight line.

Fig. 108.

BRACHIOPODA OF THE UPPER SILURIAN.



1. Rhynconella abrupta. 2, 3. Rhynconella vellicata. 4. Pentamerus galeatus. 5. Pentamerus Vernuieli.

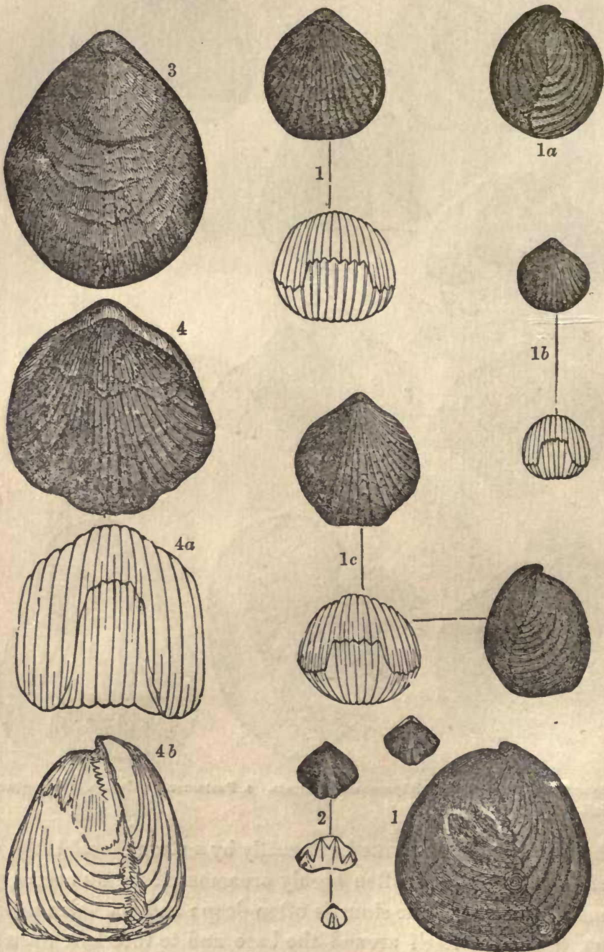
The Rhynconella is marked externally by a strong mesial fold, and the shell is ribbed and often highly ornamented by numerous plications of the ribs. The sinus is often deep; and one valve appears always to extend itself around the base and to interlock upon the opposite side.

They appear to be closely united both to the Terebratula and the Atrypa.

The Pentamerus galeatus (fig. 4), is the characteristic fossil of the lower Pentamerus limestone.

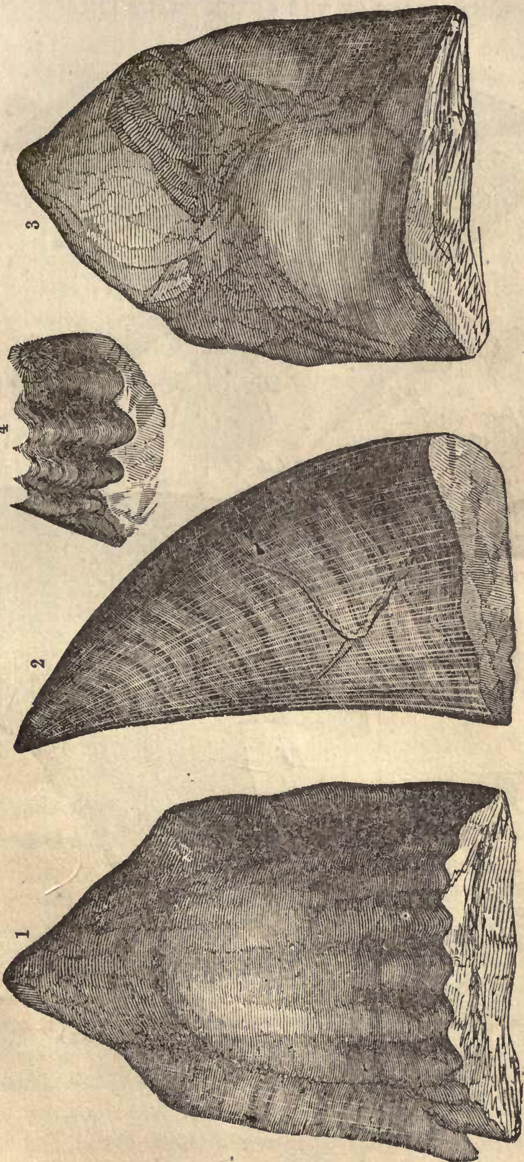
Fig. 109.

BRACHIOPODA OF THE UPPER SILURIAN.



1, 1 *a*, 1 *b*, 1 *c*. Rhynconella mutabilis. 2. Rhynconella semiplicata. 3. Rensselaeria æquicostata. 4, 4 *a*. Rhynconella nobilis. 4, 4 *a*, 4 *b*, Rhynconella nobilis.

Fig. 110.

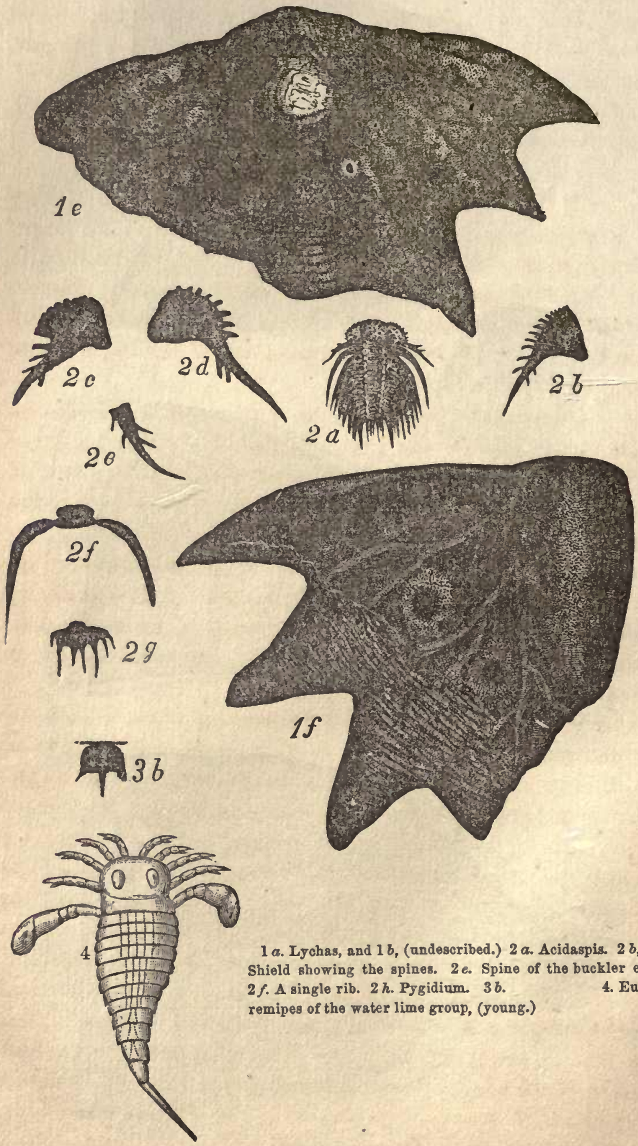


Platyceras plicatum.

1. Anterior side. 2. Left side. 3. Posterior side. 4. Folds of the anterior side.

Fig. 111.

CRUSTACEANS OF THE GREEN SHALY LIMESTONE.



1 *a*. Lychas, and 1 *b*, (undescribed.) 2 *a*. Acidaspis. 2 *b*, and 2 *d*. Shield showing the spines. 2 *e*. Spine of the buckler enlarged. 2 *f*. A single rib. 2 *h*. Pygidium. 3 *b*. 4. Eurypterus remipes of the water lime group, (young.)

At certain places, as at Becraft's Mountain, and at Schoharie, a gray limestone succeeds which is full of a peculiar species of pentamerus. It is only a few feet thick. According to the present views of geologists, this last mass is the last also of the Silurian System. It may, therefore, be seen that the upper part consists of a series of pure and impure limestones. It will be evident, too, that the threefold division of this system is convenient, and aids the memory of the student.

The greenish shaly limestone of the Helderberg range of New York is probably one of the richest rocks in fossils of the Upper Silurian System: and yet this rock seems to be quite limited in extent. It ranges west to Cooperstown, becoming gradually thinner; it however carries its fossils to its western limit. It is well developed in the Becraft Mountain, three miles east of Hudson and west of Catskill, N. Y.

The bed containing the Lychas is quite limited; the species itself is closely allied to the Lychas boltoni of the Niagara group. The Acidaspis is also quite rare, and limited to a thin stratum of rock in the green shales of the Upper Silurian. The spines of this genus furnish a clue to its recognition.

The Eurypterus remipes is the characteristic crustacean of the water lime. It is furnished with eight tentacular organs, four being placed on each side of the head. Its organs of locomotion were similar to oars, rather than feet. The tail is attenuate and sharp-pointed.

Under the name and form of *Cliff limestone,* which is both silicious and magnesian, this group is widely extended in Indiana, Ohio, Illinois, and Wisconsin; and is 7 to 800 feet thick. This limestone supports a coralline and shelly limestone which is represented in New York by the Onondaga and corniferous limestones of the Devonian system. It will, therefore, be observed that several rocks which are important eastward are absent in the west: viz., the whole of the Onondaga salt group, the water limes, Pentamerus limestone, Delthyris or green shaly limestone, Encrinal limestone, and Upper Pentamerus limestone. The student will understand from the foregoing facts that the Silurian is more complete in New York than in the Western States. The lower mass of the Cliff limestone represents the Upper Silurian, and yet there is a mixture of Upper and Lower Silurian fossils, as the Illænus crassicauda, Leptæna alternata, and Phacops caudatus.

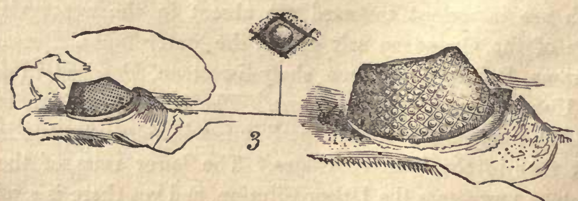
Table showing the equivalency of the New York members of the Upper Silurian with those at a distance.

New York.	*Western States.*	*England.*
Onondaga salt group. Niagara limestone. Coralline limestone. Niagara shale.	Inferior part of the Cliff limestone of the Ohio geologists equivalent to Upper Silurian.	Wenlock limestone and shales and Gothland.
Clinton group.	Niagara and Clinton groups in part, containing Pentamerus oblongus and Phacops caudatus.	Stage above the Caradoc sandstone.

In England the stage represented here by the Clinton group being intermediate between the Wenlock and Caradoc, is not represented there by any yet described series; unless by Sedgwick, who places the Mayhill sandstone and Woolhope limestone in a position parallel with our Clinton group.

The Silurian System occupies large areas in the northern, western, and southern parts of the United States. The Lower Silurian skirts the eastern shore of Lake Champlain, and exists in detached and isolated outliers in the Hudson River Valley; and small patches of the calciferous sandstone occur as far east as Hoosic, Rensselaer Co., N. Y. West of Champlain it extends west as far as the parallel of longitude of 97°, and as far south as Tuscaloosa in Alabama. Its westward and southward extent therefore is about 1500 miles. At these extreme southern and western limits the system disappears under the cretaceous and tertiary rocks. On the north-western, eastern, and south-eastern borders it rests unconformably upon the Taconic System.

Fig. 112.



Eyes of Trilobites, showing that the eyes of insects of the present day are constructed on the same plan. 3. Enlarged lens.

CHAPTER XIII.

DEVONIAN SYSTEM.

138. THIS system, though much thicker than the Silurian, is geographically less extended in this country. Like the Silurian, it is one of the general systems, and is found, it is believed, in all the great natural divisions of the earth's surface.

All such systems indicate certain uniformities in the operations of nature, as well as simultaneous movements which produced analogous results in the same epochs in the history of the earth. In no epoch, however, do we find perfect uniformity in the quantity of sediment by which the length of this epoch is measured. Remarkable differences are found when the eastern and western series constituting this system are examined. Certain subordinate groups of the system are wanting, and in others the system does not exist at all, and the Carboniferous, the next system above, lies directly upon one of the members of the Silurian. Thus, in Kentucky one member of the Devonian only exists: the Genesee slate is the only rock separating the Carboniferous from the Silurian.

In Ohio the members of the Devonian, which intervene between the Carboniferous and the Silurian, are parts of the Chemung group. They are called *Olive sandstones,* the Genesee slate, Niagara group or part of the Cliff limestone.

In New York this system is very thick, and is divisible into many groups; but westward and south-westward it constantly diminishes in thickness, and ultimately disappears.

In England and Scotland the Devonian holds an important place. It was the field of Hugh Miller's most valuable and popular labors. In England the thickness of the Devonian is eight thousand feet.

Mr. Lyell states that on the coast of Rosshire the old red sandstone forms isolated hills resting on gneiss; the strata are horizontal, and only three thousand feet thick in consequence of denudation. In this region it is evident from the diminished thickness and the

insulation of the hills, that forces or agents have worn off, and cut down these strata to the very base on which they rest.

But the most interesting fact to us is the co-ordination of these distant beds with our own, being shown by the similarity of fossils, or the close affinity of fossils which identifies this distant formation with our own. Thus the remarkable fish, the Holoptichius nobilissimus, is common to both countries; the asterolepis, upon which Hugh Miller bases his celebrated argument against the transmutation theory, is also common to both countries.

This system in New York is composed of the following rocks and groups of rocks. Oriskany sandstone, two to three feet thick, but between 600 and 700 feet in Pennsylvania; Cauda galli grit and Schoharie grit, seven to ten feet thick; Onondaga limestone and corniferous limestone, 120 feet thick; they really form but one rock. Marcellus shale, Hamilton group, Tully limestone, only 14 feet thick; Genessee slate, Chemung group, and Cattskill group. According to M. De Verneuil, the lowest rock of this system in New York is the Oriskany sandstone. If we take the Helderberg and Cattskill Mountain group as the type of the system, we shall find two zones of shales and sandy beds; one below and one above, with a heavy limestone formation between. The sandstones and sandy beds embrace the Oriskany sandstone, the cauda galli grit, a dark drab-colored silicious shale, above which there is another grit only seven or eight feet thick, called the *Schoharie grit;* it is important only as the repository of many fossils. Upon these repose the Onondaga and corniferous limestones.

The latter passes into shales, which are soft, dark-colored or black, and in some parts quite calcareous. They contain many peculiar fossils, and they have become generally known as Marcellus shales. The Hamilton group, which succeeds, consists of shales and silicious beds and sandstones, which are generally thin-bedded and dark-colored, but weather to a brown. Among the shales there are impure calcareous bands, and calcareous matter is disseminated to a small extent through different bands of the formation: these are the best repositories for fossils.

The Tully limestone succeeds the Hamilton group; it is only 14 feet thick. Upon this limestone the Genesee slate reposes; it is thin-bedded, black, and calcareous.

Fig. 113.

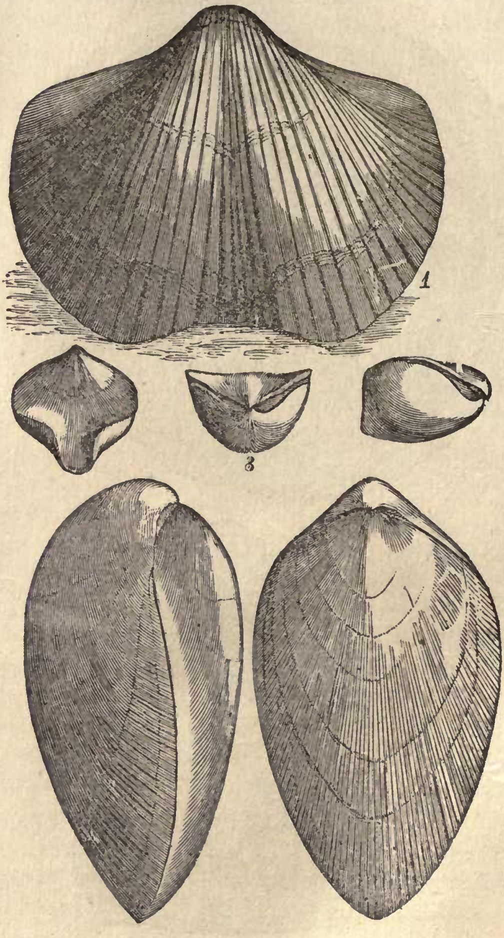
RHYNCONELLA BARRANDI.

1. Side view, showing its ridges. 2. Back view.—It is believed to be confined to the Oriskany sandstone—the lowest member of the Devonian System.

The Rhynconella Barrandi is rather common at Cumberland, Md. It is one of the largest of this genus.

Fig. 114.

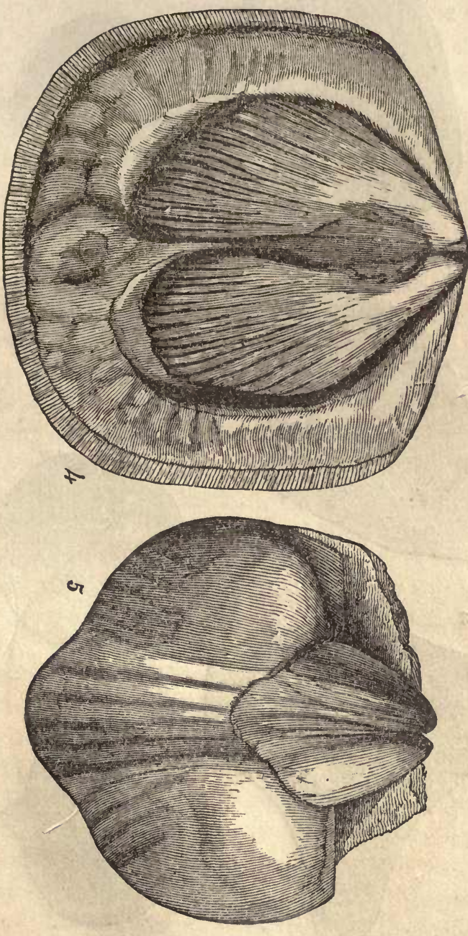
SPIRIFER ARENOSUS.



1. Spirifer arenosus. 2. Rensselaeria ovoides. 3. Etonia peculiaris.

The Spirifer arenosus is the most common fossil of the Oriskany sandstone. It often occurs in casts. See 111.—5.

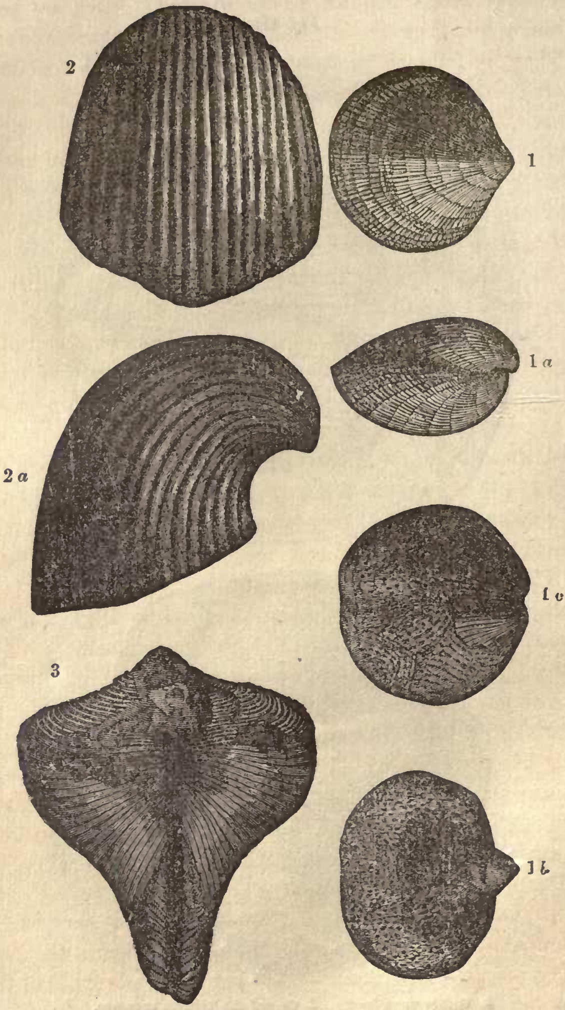
Fig. 115.



4. Orthis unguiformis. 5. Cast of the Spirifer arenosus.

The Oriskany sandstone, though thin in New York, contains probably all the fossils which strictly belong to the rock. It is often a mass of shells or the cast of shells.

Fig. 116.



P. Sagittatus. Enlarged.

1, 1 *a*, 1 *b*. 1 *c*. Atrypa impressa. 2. Pentamerus aratus. 2 *a*. Side view. 3. Pleurorl [illegible]

The mass to which the foregoing fossils belong is crowded with them, but they are frequently in the condition of casts.

The Portage and Chemung groups succeed. They are partly shales passing into flagging-stone and rarely into thick-bedded sandstone. They are followed by the Cattskill group, which consists of dark-colored shales which frequently alternate with red shales and sandstones. It has been regarded as the equivalent of the old red sandstone of England and Scotland. It forms the greater portion of the Cattskill Mountains. Conglomerates occur at the top of the Cattskill rocks belonging probably to the carboniferous system.

The Devonian System does not exist east of the Hudson River. West of the Mississippi the Devonian is represented by either the Portage or part of the Chemung group.

The fossils of the Devonian are exceedingly numerous, and differ remarkably from those in the Silurian. Its most interesting fossils are fish, among which the ganoids are conspicuous. In this system reptiles begin their career, but they are feebly represented, and only foreshadow the future of this important class. In Europe only two reptiles have as yet been discovered; the Telerpeton of Mantell, and the Staganolepis; the former is supposed to belong to the Batrachian family; the latter has a close resemblance to the Teleosaurus. Plants which bear a resemblance to coal plants, and are undoubtedly of terrestrial origin, begin to appear in the upper part of the system. Corals and mollusca abound throughout.

The foregoing groups collectively compose the Devonian System. The rocks from the Genesee slate to the conglomerate at the top of the Cattskill, constitute really but one series, though for convenience it has been subdivided into groups. The deepest part of the Devonian sea appears to have been in the region of the Cattskill series. The prolongation of the Devonian and Silurian eastward is quite limited. There is no Devonian on the east side of the Hudson River. The Upper Silurian is prolonged four or five miles eastward of the city of Hudson, and forms the upper part of Becraft's Mountain, where it suddenly disappears towards the east.

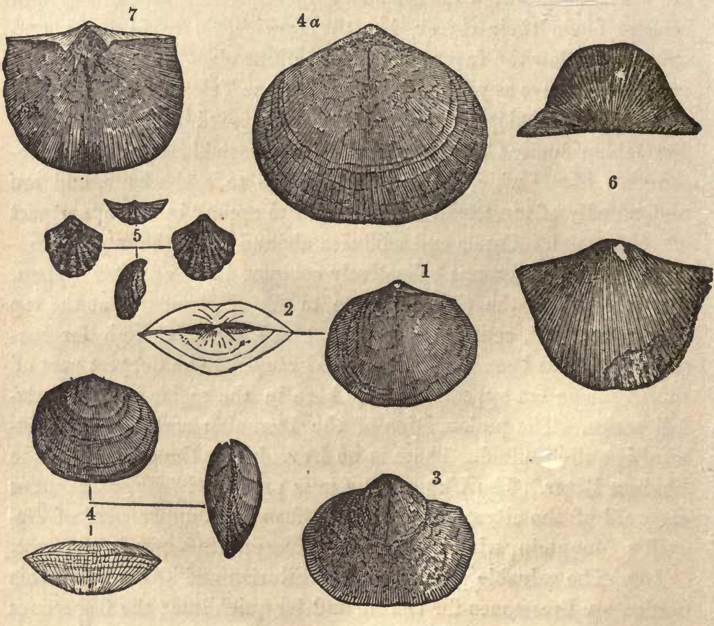
139. The valuable products of the Silurian and Devonian of this section are limestones for marble and for quicklime; the flag-stones belong exclusively to the Devonian. No ores or coal belong to either system in this part of the state. There are no limestones proper above the Tully limestone.

The Devonian in Ohio is much thinner than in New York. Its members are called, 1st. Olive-colored sandstone, which are equivalent to the Chemung group in New York; the Marcellus shales,

100 feet thick, and the Cliff limestone, the upper part of which is equivalent to the corniferous limestone which reposes directly upon and is conformable to the blue limestone in part of the west, and which is the equivalent of the Lorraine shales. In the South-west, in the county of Wythe, the Devonian is not recognisable, the carboniferous resting directly upon the Upper Silurian, or the Clinton and Niagara groups: this is the case in certain places, and if the Devonian exists at all, it is in exceedingly thin masses, and will be found the equivalent of the New York Chemung group.

Fig. 117.

FOSSILS OF THE MIDDLE DEVONIAN SYSTEM, OR HELDERBERG LIMESTONE.

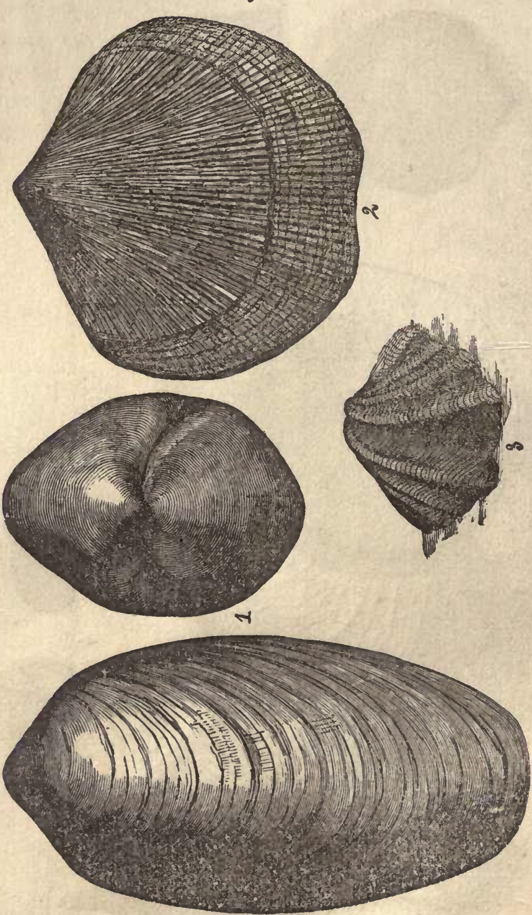


1, 2, 3. Orthis subcarinata. 4. Orthis oblata. 4 *a*. Orthis perelegans. 5. Spirifer. 6. Chonetes hemisphericus of the Schoharie grit. 7. Strophomena.

Fig. 118.

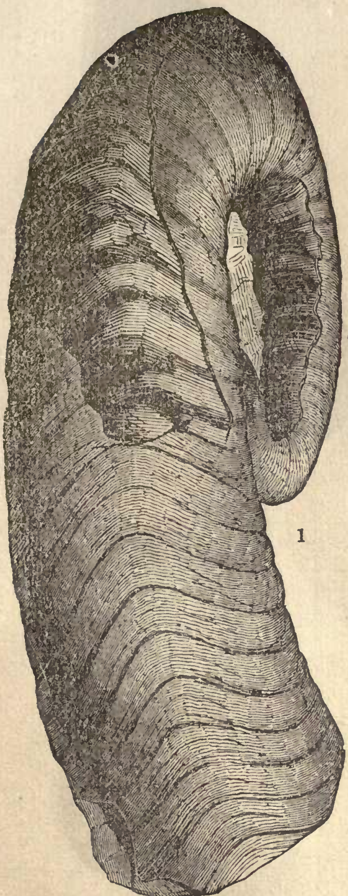
1. Dalmania selenurus. 2. Cyrtoceras undulatus. 3. Chonetes lineata. 4. Orthis lenticularis. 5. Atrypa reticularis. 6. Transverse section of an Ichthyodolerite.

Fig. 119.

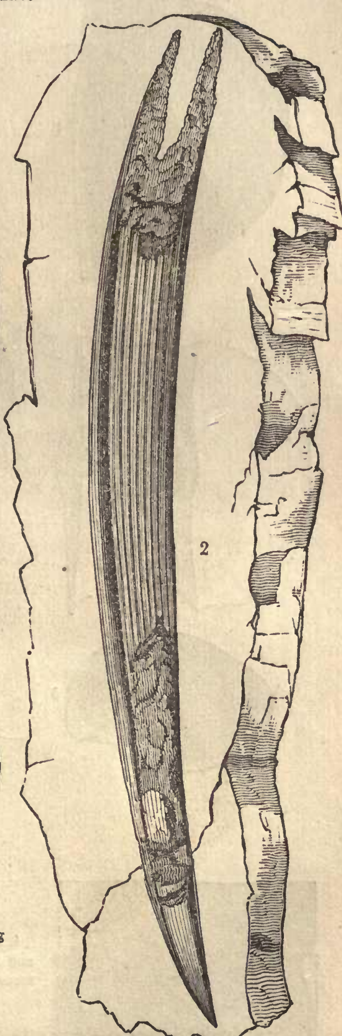


1. Rensselaeria (Meganteris) elongata (Hall). 2. Atrypa reticularis. 3. Spirifer undulatus.

Fig. 120.

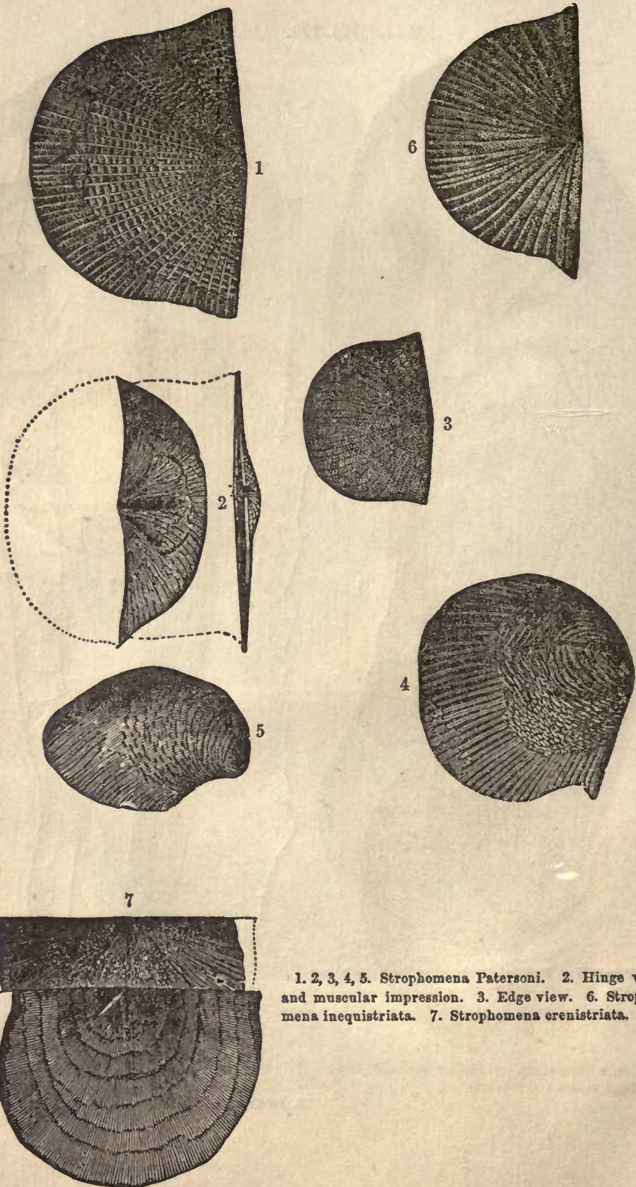


1. Cyrtoceras. Back view, showing the undulating septæ.



2. Ichthyodolerite of the Onondaga Limestone.

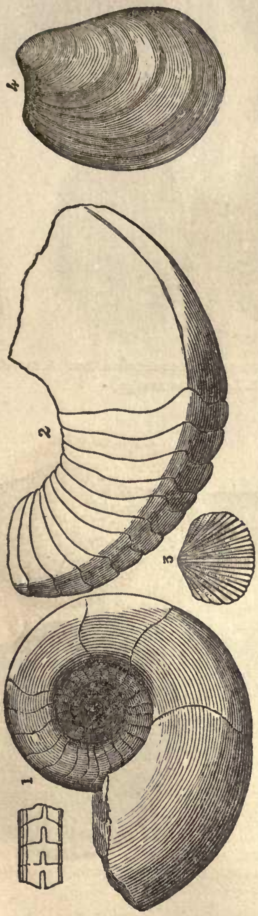
Fig. 121.



1. 2, 3, 4, 5. Strophomena Patersoni. 2. Hinge view and muscular impression. 3. Edge view. 6. Strophomena inequistriata. 7. Strophomena crenistriata.

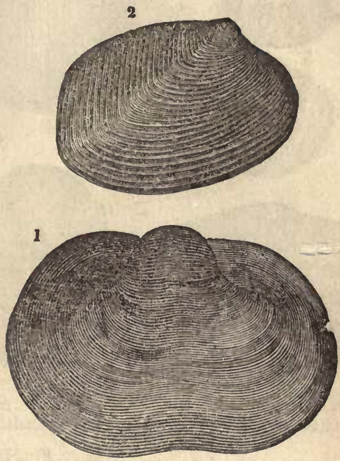
MARCELLUS SHALES.

Fig. 122.



1, 2. Goniatites. 3. Orthis limitaris. 4. Cypricardia marcellanus.

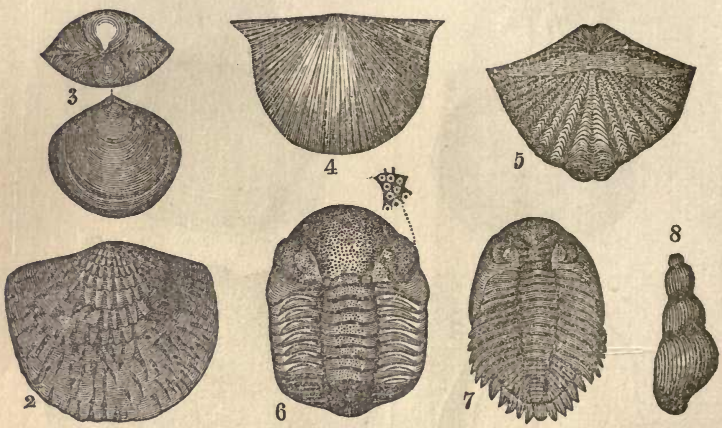
Fig. 123.



1. Bellerophon patulus. 2. Microdon bellastriatus.

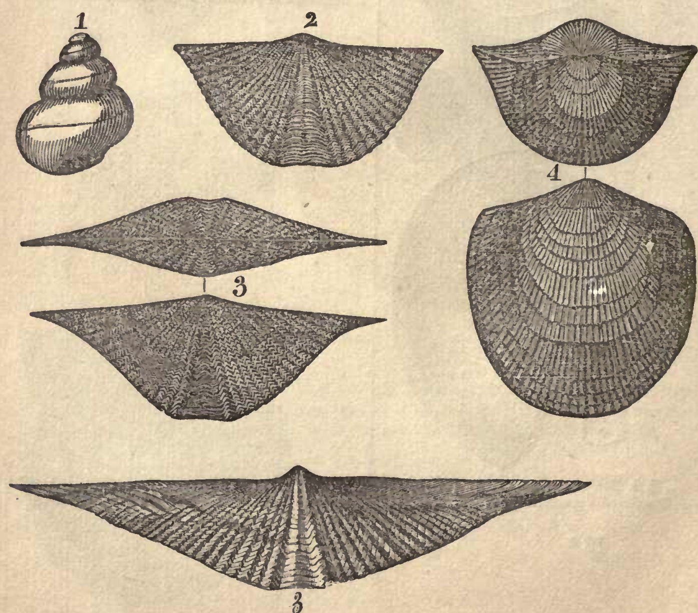
Fig. 124.

HAMILTON GROUP.



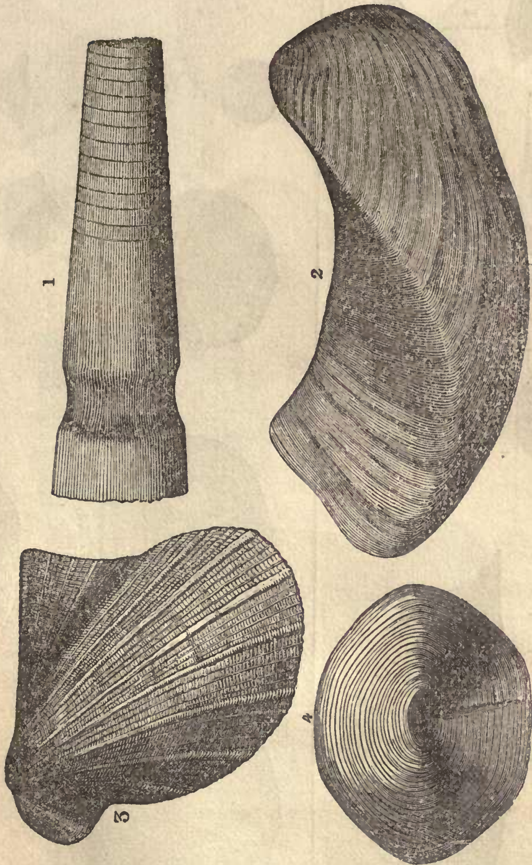
2. Atrypa spinosa. 3. Nucleospira concinna. 4. Strophomena inequistriata Con. 5. Spirifer zigzag (Hall). 6. Phacops bufo. 6. Dalmania calliteles. 8. Loxonema nexilis.

Fig. 125.



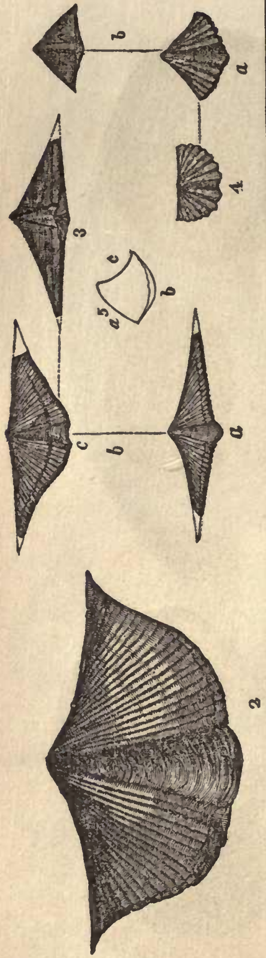
1. Pleurotomaria lineata. 2, 3, 3. Spirifer mucronatus. 4. Atrypa prisca.

Fig. 126.



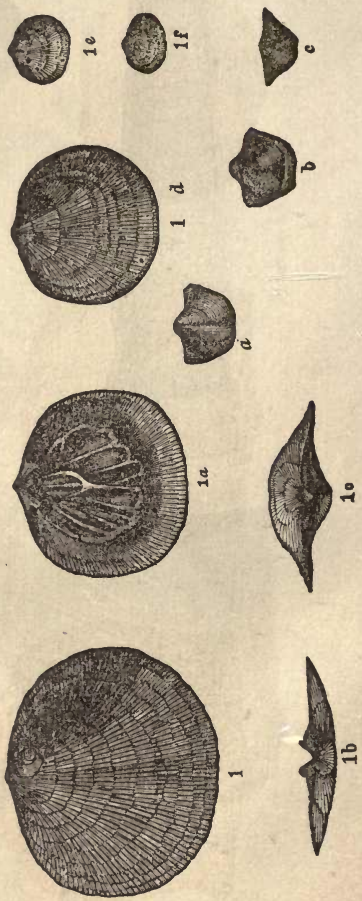
1 Orthoceras constrictum. 2. Cypricardites recurva. 3. Avicula flabella. 4. Discina grandis.

Fig. 127.



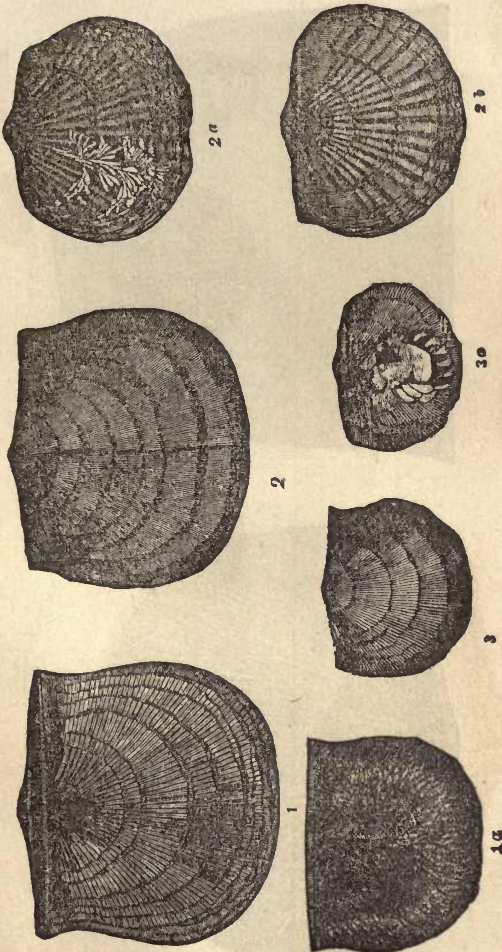
2. Spirifer medialis. 3. Spirifer angustus. 4. Cyrtia Hamiltoniensis.

Fig. 128.



1, 2, 3, 4, 5. Orthis Vanuxemi. 1 *c*. Hinge view. 1 *b*. View of the Ventral Valve. *a*, *b*, *c*. Orthis umbonatus.

Fig. 129.



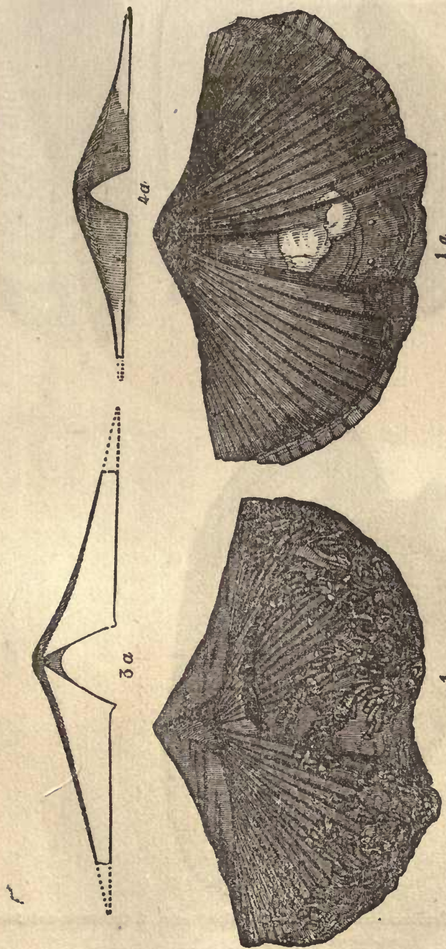
2 *a*, 2*b*. Tropidolepus carinatus. 1, 2. Strophomena demissa. 1 *a*. Muscular impression. 2 *a*. Young.

Fig. 130.

2. Strophomena concava.

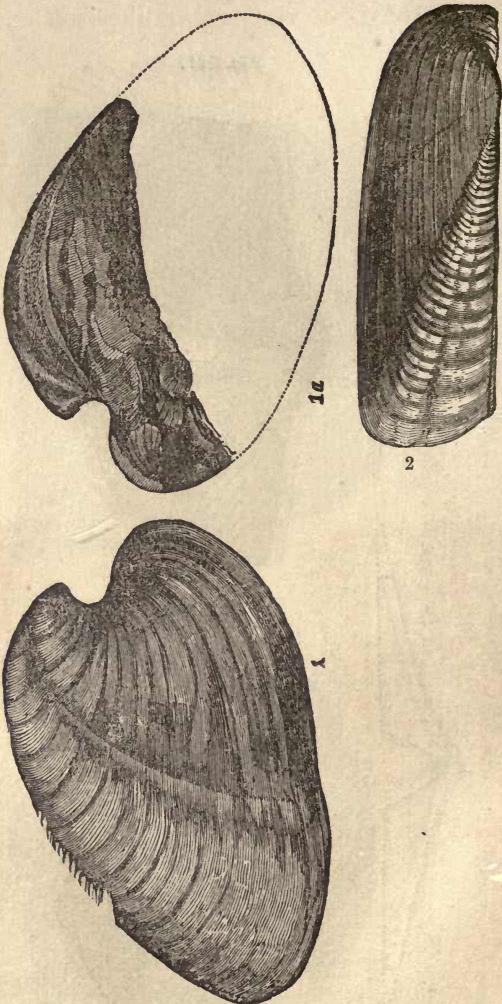
1. Strophomena textilis.

Fig. 131.



Spirifer Marcyi. *3a, 4a.* Hinge views.

Fig. 132.



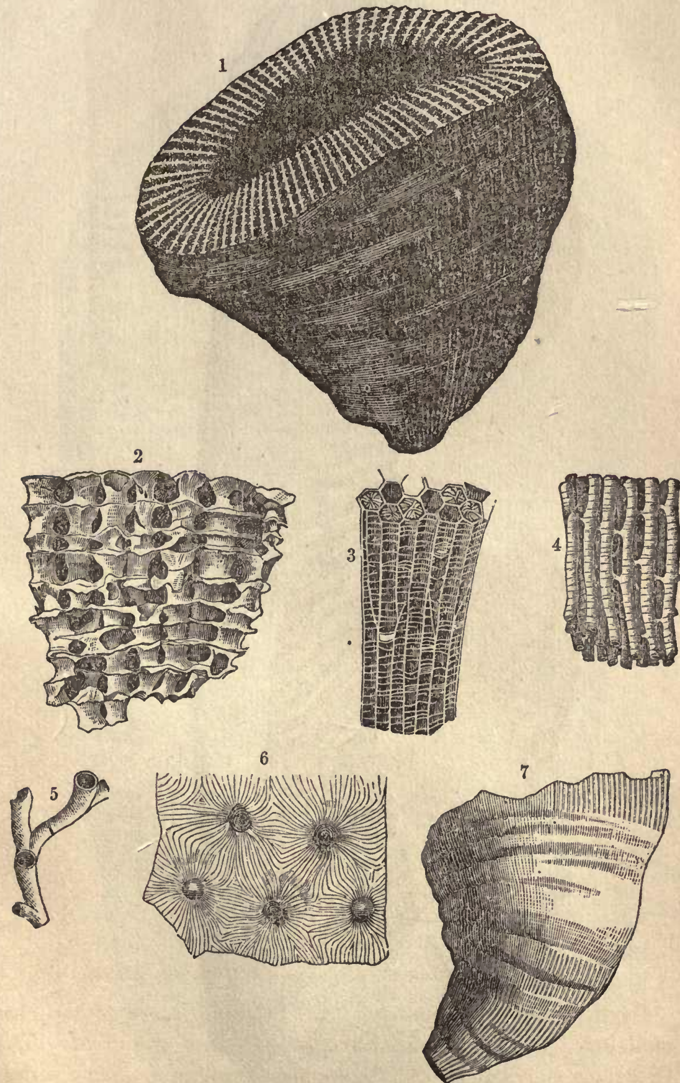
1, 1 a. Cypricardites (Gramysia) Hamiltoniensis. 2. Orthonota undulata.

Cypricardites, or Gramysia of De Vernueil, is one of the characteristic fossils of the shales and sandstones of this group. The Orthonota is by no means an uncommon fossil in the same series.

The Helderberg Mountains, Albany, Co., N. Y., and the ranges of mountains in Schoharie County, are also depositories for the fossils of this group.

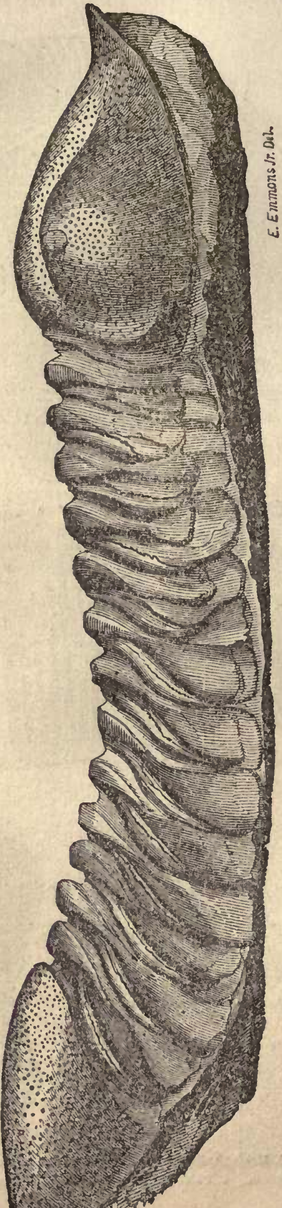
Fig. 133.

CORALS OF THE DEVONIAN SYSTEM.



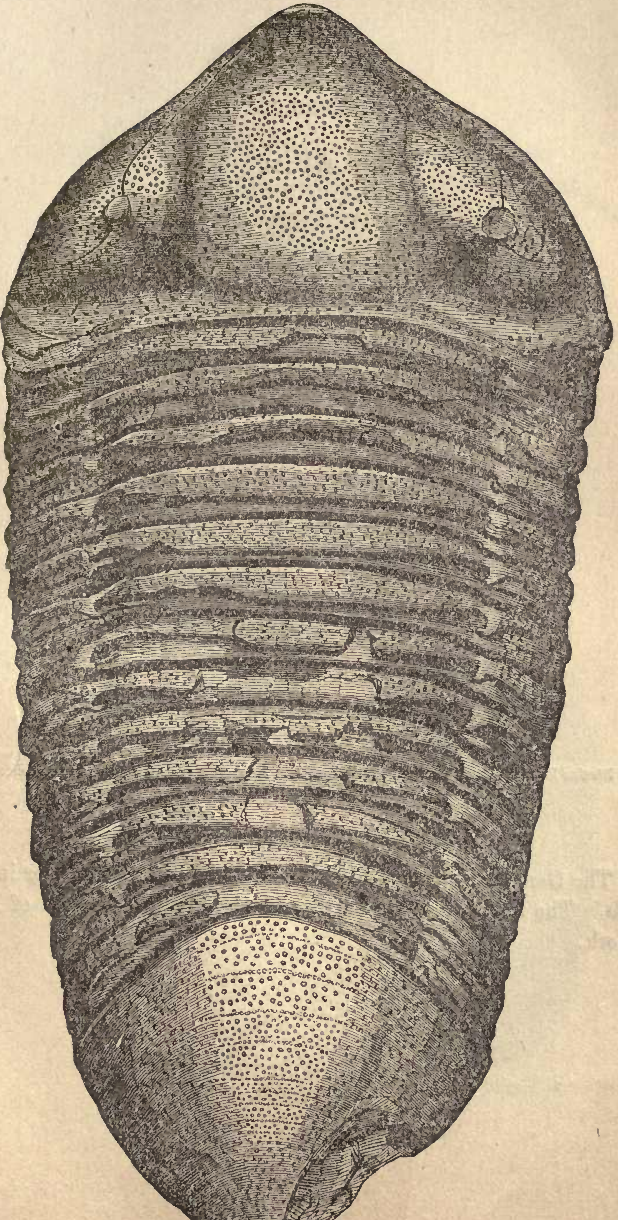
1. Heliophyllum Halli. 2. Eridophyllum simconensis. 3. Favosites gothlandica. 4. Syringopora elegans. 5. Aulopora cornutum. 6. Phillipsastrea verneuili. 7. Zaphrentis prolifera.

Fig. 134.



Homalonotus Dekayi. Side view.

Fig. 135.



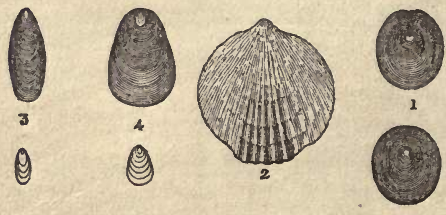
Homalonotus Dekayi. Back view.

GENESEE SLATE.

Fig. 136.

2, 2. Avicula fragilis. 3. Chonetes setigera. 4. Tentaculites fissurella.

Fig. 137.



1. Discina lodensis. 2. Rhynconella quadricostata. 3. Lingula spatulata. 4. Lingula concentrica.

The Genesee slate is a black fissile rock, and rather poor in fossils. The fossils, too, are small and obscure in the state of New York.

Fig. 138.

CHEMUNG GROUP.

1

3

3 *a*

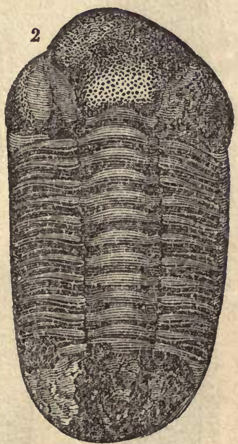
3. Avicula Chemungensis. 3 *a*. Hinge view.

2

2 *a*

1, 2, 2 *a*. Bellerophon cyclopetrus. 1. View of the top. 2 *a*. Side view.

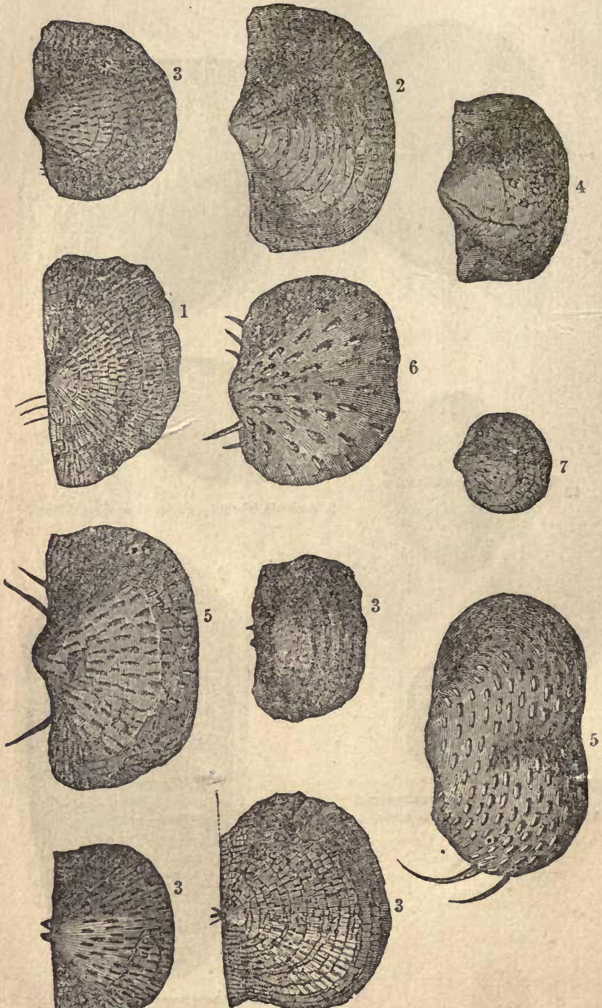
2



2. Phacops nupera of the Chemung Group.

Fig. 139.

CHEMUNG GROUP.



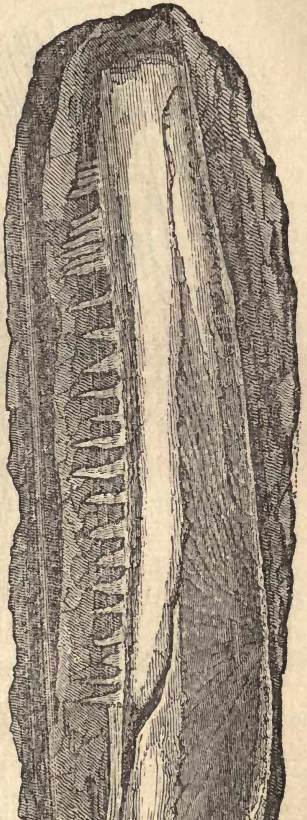
1, 2, 3. Productus hirsutus. 4. Productus rarispinis. 5, 5, 6. Productus Boydii. 7. Young of hirsutus.

Fig. 140.

CATSKILL GROUP, OR OLD RED SANDSTONE.

1. Cypricardites angustata.

Solen subrotundus, E.

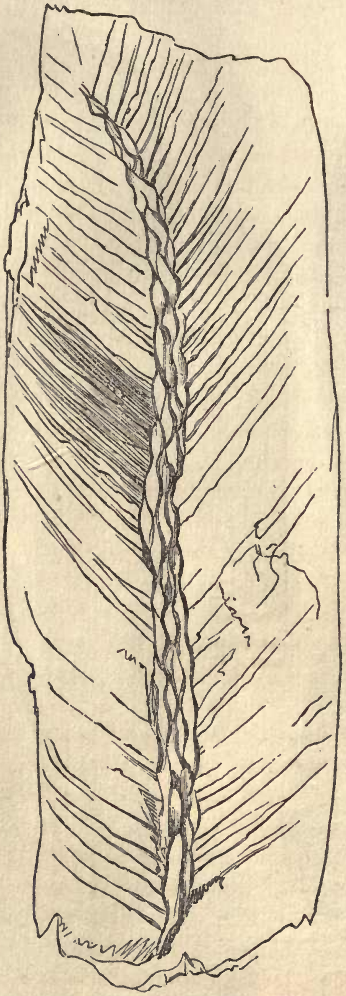


2. Jaw of Holoptichius Taylori ?

Spirifer catskilensis.

Terebratula lepida.

Fig. 141.



Lepidodendron? Devonian Plant.

CHAPTER XIV.

CARBONIFEROUS SYSTEM—AN IMPORTANT EPOCH—A STAND-POINT FOR RECKONING GEOLOGIC TIME, VEGETATION, COAL, AND PROSPECTIVE MATERIAL DESIGNED FOR THE USE OF MAN—FORMATION ILLUSTRATED—VEGETABLE FOSSILS—DIVISION OF THE SYSTEM INTO LOWER CARBONIFEROUS, AND THE COAL MEASURES, ETC.—RECAPITULATION.

140. THIS system fills the most important epoch in the earth's history. Unlike the Devonian and Silurian, it abounds in useful products, and these products, taken collectively, have been the most direct and efficient agents in promoting that high degree of civilization which now prevails. Of these valuable products, coal is the most essential material, and from its abundance in this system it has derived its distinctive name, the *Carboniferous System.*

To the geologist it is often a point of departure for his reckoning of geologic time, or it may be employed for determining his true position in the geologic scale, as it occupies a mid position; and hence the past and future are necessarily in certain determinable relations which may be viewed with great advantages from this stand-point.

Of all the systems, too, it is more constant and uniform in its characteristics, when continents or large areas are compared, than those which succeed it. This statement applies both to its fossil remains and its mineral constitution.

141. It was in this epoch that the earth began to wear a fairer and more promising aspect. It was clothed with a vegetation which would be prized by civilized man. It was a period when forests of coniferous trees adorned the land; and if compared with the Devonian, it would present a striking contrast, as the latter has preserved no trees or forests, and hence it is probable would appear as an arid or barren waste. Previous to this time we have only feeble indications that the earth was watered, as it is now, by showers of rain.

In the carboniferous series, however, there were soils which bore land plants, and trees of a large growth; as we now find their remains in an erect position with their roots still fixed in the earth in which they grew. So also the sandstones and shales contain prostrate trunks, denuded of limbs and bark, which must have drifted down rivers and finally into the ocean, where, becoming water-logged, they sank, and were buried under mud and sand.

The vegetable kingdom, then, as it is represented in these relics, furnishes unmistakable evidence of progress. Besides, we look back to this epoch with great interest for its prospective products, its coal especially, which we believe we are warranted in regarding as a special provision for man. We can view in no other light these great deposits of fuel, which required ages for its growth and subsequent consolidation to fit it perfectly for the parlor, the workshop, and steam-engine.

142. It is proved by direct observation, that coal is of vegetable origin. By the aid of the microscope, it is found composed of the vegetable tissues; almost every particle has preserved in its substance ducts or vessels, organs of growth which are peculiar to the vegetable kingdom; hence, although it is enclosed in beds of rock, it has an origin out of the pale of the mineral kingdom.

To illustrate the circumstances and the succession of events which were connected with each other in the production of coal and the formation of the accompanying beds, we may refer to peat, a substance which we know has a vegetable origin. In the first place, peat is formed only in cool wet places. If the temperature is much above 75° or 80°, the vegetable matter is consumed; for example, in the eastern counties of North Carolina peat is formed, while in the middle counties, though the surface is protected by forests, it is not found, neither is there a trace of black vegetable mould. Though there is an annual addition of vegetable substance to the surface; it is all consumed.

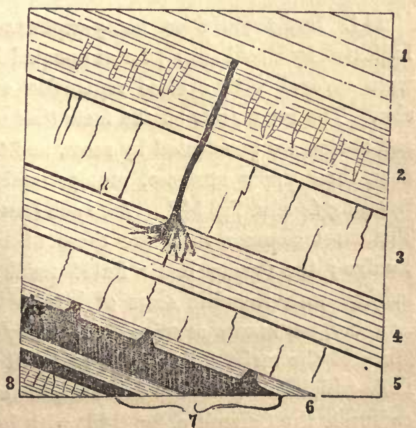
But the low grounds of the eastern counties being wet and swampy, the temperature never reaches that point at which a slow combustion takes place, as is the case in the middle counties. So also we infer that coal plants grew only in grounds which were wet and cool, though the temperature of the uplands may have been comparatively high as at the present time. It is agreeable then with what we know of the conditions required to preserve vegetable matter,

and convert it into coal, that a low temperature must have prevailed over those areas.

143. Peat occurs only in single beds; but in the coal measures numerous beds of coal occur one above the other, which are separated by a variety of mineral products. Here then the similarity in the circumstances attending the production of peat and coal ceases. It becomes necessary to explain how several beds may have been formed in succession and over the same area, for it is plain that each bed was formed at the surface and bounded by the air above, and by the wet soil below; and that each coal area, as in the case of peat, must have been covered with growing vegetables while the surface was virtually stationary.

To account for the occurrence of successive beds of coal, it is supposed that after a stratum of vegetable matter had been accumulated, a subsidence took place by which the surface was submerged beneath the water, and that sand, clay and pebbles, materials derived from neighboring hills, or from distant parts, which would be brought down by rivulets and streams, would in time form a sufficient accumulation of debris to fill up the basin or estuary; thus forming a swamp or morass upon which a new vegetation would spring up and furnish new matter for another bed of coal. We may consider then that repeated subsidences must have taken place after intervals of rest, and it was during those intervals of rest that beds of sandstone, shale, underclays, &c., were deposited.

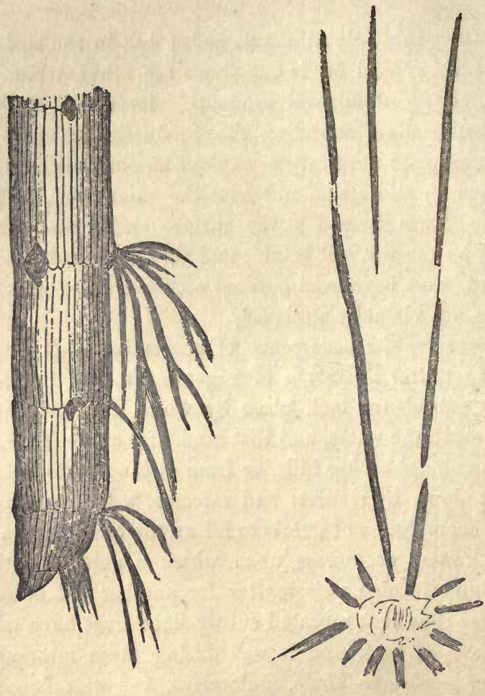
Fig. 142.



This figure includes the following beds as occurring in the Nova Scotia coal measures.

1. Shale and sandstone. 2. Slate and sandstone with erect calamites. 3. Gray sandstone 7 feet. 4. Gray shale 4 feet, with an erect coniferous tree. 5. Sandstone 4 feet. 6. Gray slate 6 inches, with erect and prostrate trees, rootlets, leaves, and a modiola. 7. Main coal measures 3 feet 6 inches. 8. Underclay with roots.

Fig. 143.



Calamites with Leaves and Roots.

144. But there were many stationary periods which are not indicated by a coal seam; for at unequal intervals areas occur which were covered with a close vegetation embracing trees of a large size. The proof rests on the facts that underclays, soft sandstones, and shales are penetrated by roots, and frequently upon what were once their upper surfaces, stumps and trunks of trees are still standing *in situ*, fig. 142. All such areas mark a stationary period. The most common roots are those of the *Sigillaria* and *Lepidodendra;* the former had a fluted trunk, the latter was singularly marked with rhombic scars of leaves. The roots of the former, however, are known as *stigmaria.* They frequently have the strong fibres of the main stem of the root still attached. Another vegetable which seems always to have grown in company with the preceding is the Calamites, fig. 143, with its fluted and jointed stems.

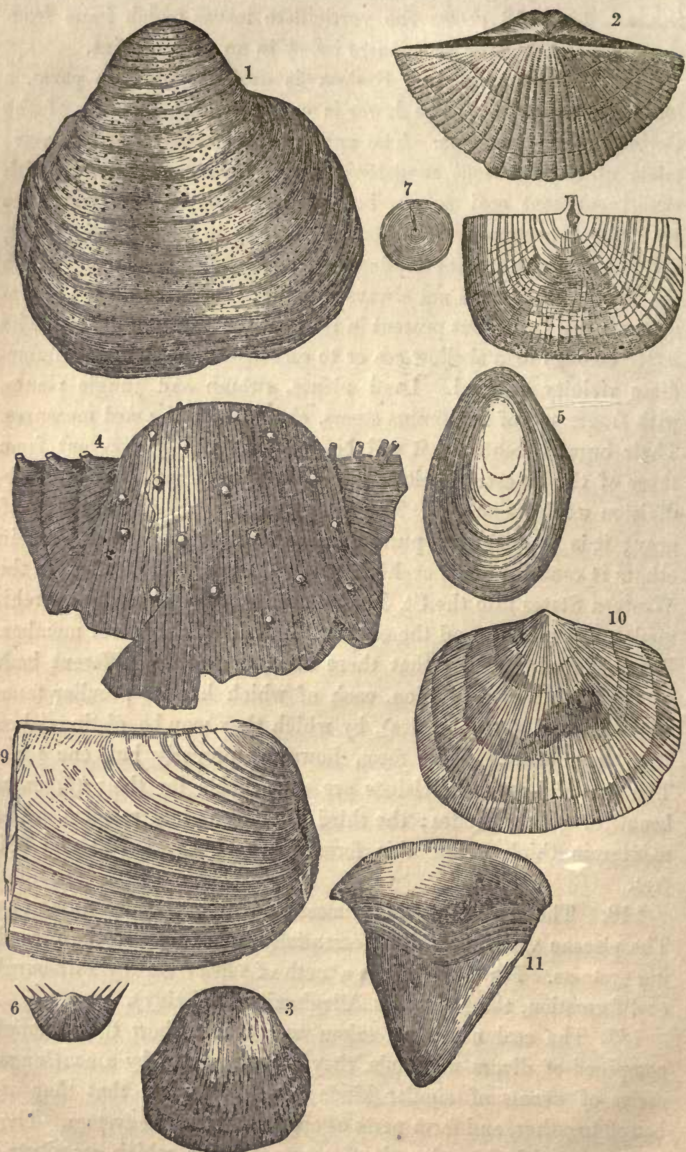
These formed jungles similar to the cane brakes of the Southern States. Fig. 143 shows the verticillate leaves which issue from the joints. The stem terminates below in an obtuse point.

145. The Carboniferous System is divided into two parts, a *lower* and an *upper*. The lower is composed lithologically of the Carboniferous limestone. The upper, or coal measures proper, are made up of micaceous sandstones, conglomerates, underclays with superincumbent coal seams, brown, gray, and bituminous shales with clay ironstones. The former belongs to a deep sea deposit, and is filled with marine molluscs, crinoids, and vertebrates, which are mostly fish. It is not always present; it is absent in the Pennsylvania coal fields, but present in those of the Western States. The latter belongs to a shallow sea or to estuaries formed in the immediate vicinity of land. Land plants, swamp and jungle plants, with fragments of coniferous stems, characterize the coal measures. Their organic contents, it will be seen, are widely different from those of the limestone below; and hence the propriety of the subdivision we have stated. The limestone is usually some shade of gray; it is frequently a pure limestone and fit for quicklime: in others it contains chert or hornstone. It has been divided in the Western States into the St. Louis limestone, the upper, the Archimedes, the middle, and the encrinal limestone, the lower member. It is believed by many that there are two or three different beds of the Archimedes division, each of which has its peculiar fenestella or coral (Archimedes), by which they may be distinguished from each other. They form, however, properly but one rock. The first and second divisions are remarkable for their numerous beautiful quartz geodes; the third for its encrinal remains. The maximum thickness of this formation is between 750 and 800 feet.

146. The fossils of this limestone are extremely numerous. The piscean vertebrates differ essentially from those of the preceding systems. Fig. 144 (11) is a tooth of a fish from the Pittsburgh coal formation, the Petalodus Alleghaniensis (Leidy).

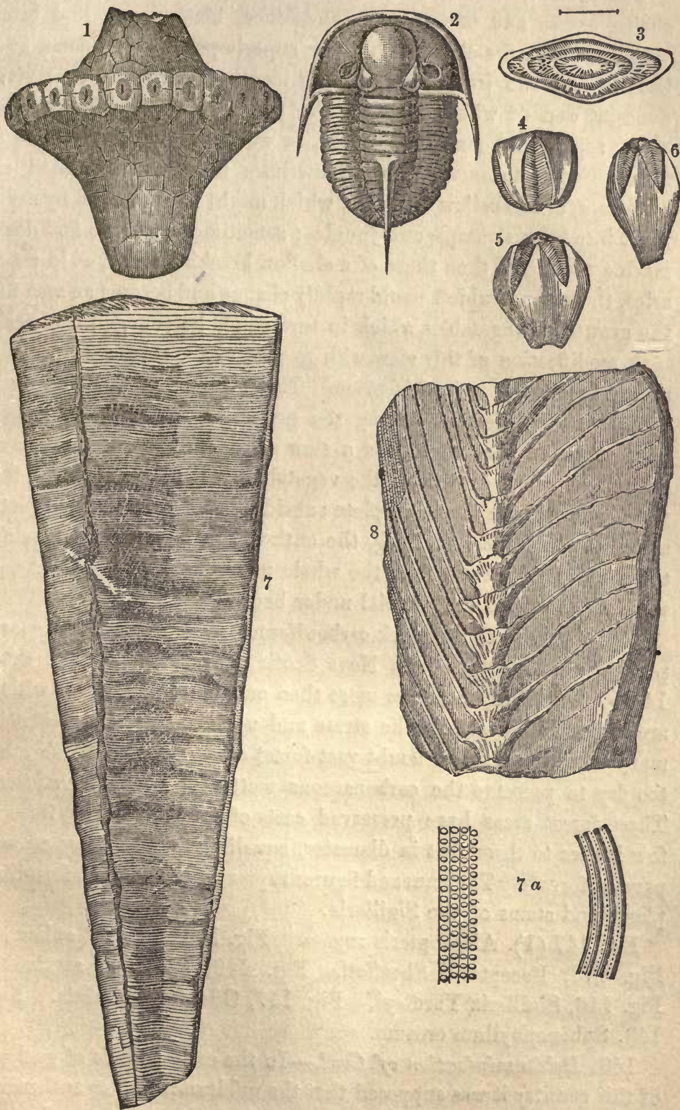
147. The coal measures, taken as a whole, show that, though composed of divers materials, they are connected by a continuous series of events of similar kinds; and also show that they are bound together, and form parts of only one period or system. They were ushered in by a deposit of coarse pebbles, which constitute a massive bed, which has been called the *Millstone grit.*

Fig. 144.



1. Productus carbonarius. 2. Spirifer Marionensis (do.) 3. Productus . 4. Productus aequicostatus. 5. Modiola. 6. Chonetes ornata (Shumard). 7. Discina. 8. Productus flemingi. 9. Allorisma Hannibalensis (do.) 10. Orthis swallovi. 11. Petalodus alleghaniensis.

Fig. 145.



1. Actinocrinus chrystii. 2. Cyphaspis girardeauensis four times enlarged). 3. Fusilina cylindrica. 4. Pentremites Sayi. 5. Pentremites Koninckana. 6. Pentremites pyriformis. 7 and 7 *a*. Conularia vernuelii (half the size). 7 *a*. surface enlarged. 8. Archimedes Wortheni.

The system, lithologically considered, is composed of grits and shales, coarse and fine-grained sandstones, black, gray, and bituminous shales, fire-clays, with their superimposed coal seams and beds of clay and ironstones, forming together a series of overlying deposits, and of which many of the members are often repeated. These repetitions could only occur, as we have already explained, by successive submergences. Sometimes these areas existed as deep seas, or as shallow estuaries, which might be converted by sediment into bays, swamps, and jungles; sometimes again we find deep marine products; then those of a shallow brackish water, as in estuaries, the latter of which would rapidly change and become an area for the growth of vegetables which in turn would be changed into coal.

A modification of this view with respect to the stationary periods should be alluded to in this place. Thus, instead of maintaining a period of absolute rest during the growth of coal plants, it has been supposed that there was a slow subsidence which kept pace with the upward growth of the vegetables. Still it is evident the time came when a more complete subsidence occurred; so complete as to submerge most perfectly the entire plant bed, and of placing them so deep in water that the whole mass was killed, and at the same time secured their burial under beds of sand and clay.

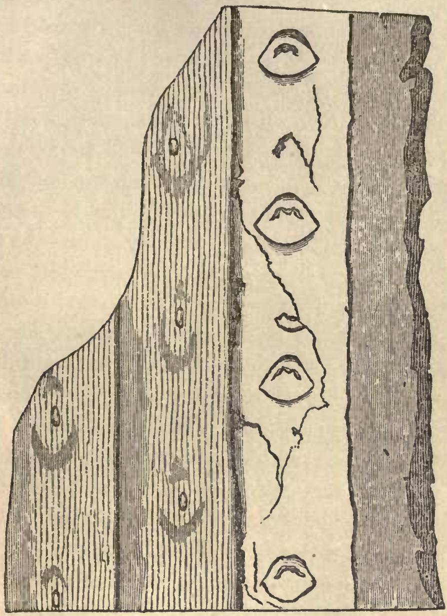
148. In many of the thick carboniferous systems these stationary periods are numerous. In Nova Scotia, where it is no less than 14,000 feet thick, there are more than one hundred; all of which are indicated by roots in the strata and upright trunks and stems, many of which were no doubt vast forest areas, parts of which were too dry to preserve the carbonaceous matter of a rank vegetation. These forest areas have preserved casts of trunks varying from a few inches to three feet in diameter, equalling in size those of our present forests. The annexed figures represent the ancient fern-like plants and stems of the Sigillaria.

Fig. 147 (1). Alethopteris rugosa. Fig. 150, A leaflet enlarged. Fig. 148, Pecopteris Sheafferi. Fig. 146, Sigillaria attenuata. Fig. 146, Sigillaria Yardleyi. Fig. 147, Odontopteris alata. Fig. 149, Sphenophyllum erosum.

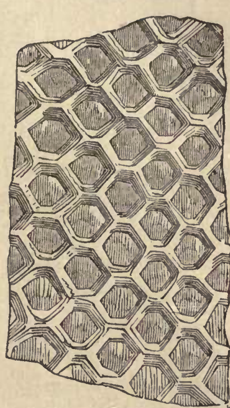
149. *Debituminization of Coal.*—In the early periods of geology of this country it was supposed that the unbituminized or anthracite coals were older than the bituminous. It is, however, now known that both varieties belong to the same epoch; the former to rocks which have been disturbed, fractured, and broken up, and which

Fig. 146.

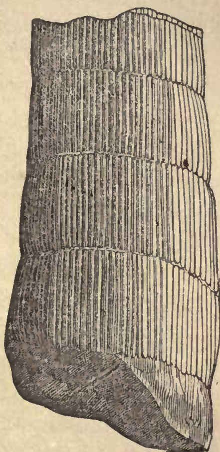
FLORA OF THE CARBONIFEROUS SYSTEM.



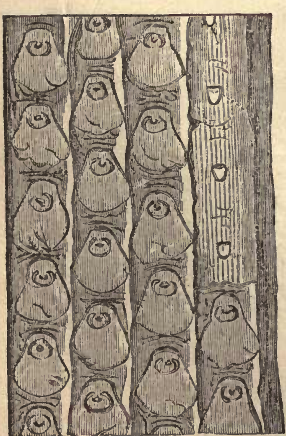
Sigillaria yardleyi (Lesq).



Sagenaria dichotoma.

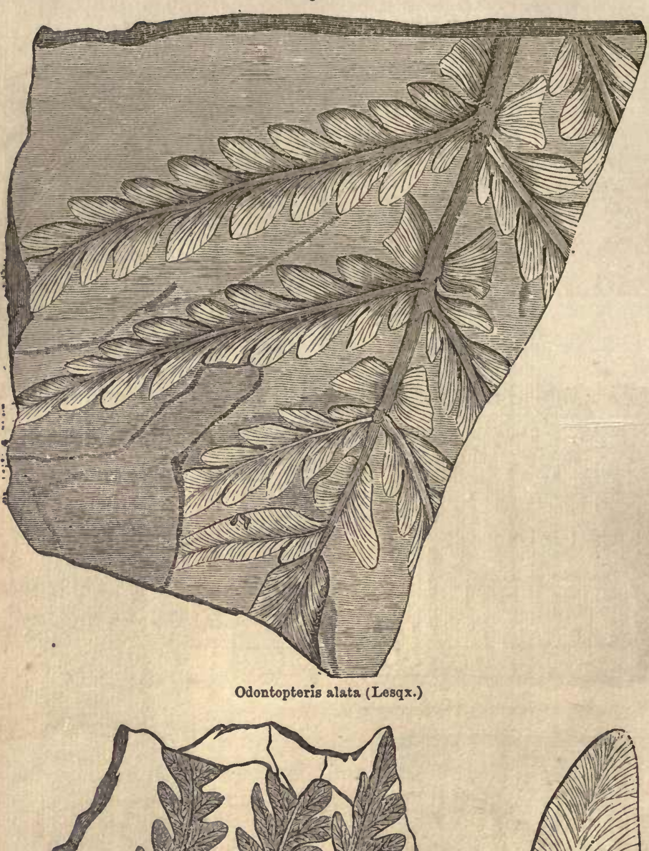


Calamites cistii.



Sigillaria attenuata (Lesqx.)

Fig. 147.



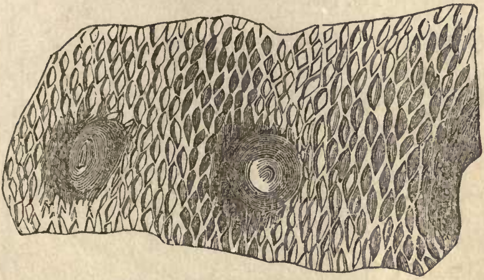
Odontopteris alata (Lesqx.)

ropteris rugosa (Lesqx.)

Neuropteris hirsuta ?

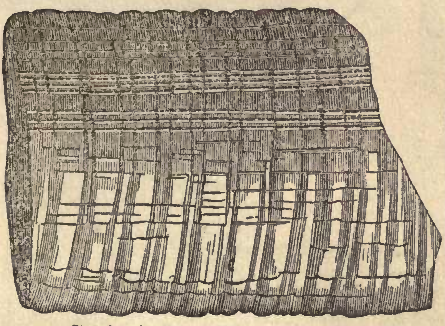
Fig. 148.

FLORA OF THE CARBONIFEROUS SYSTEM.



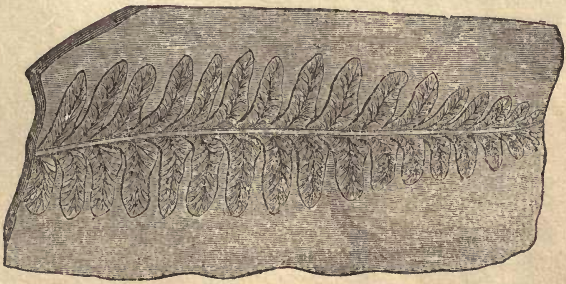
Halonia, South-western Virginia.

Neuropteris?



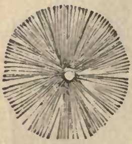
Sternbergia, Nova Scotia, Joggins coal field.

Sphenopteris?

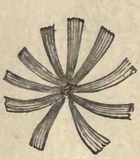


Pecopteris Sheafferi (Lesqx.)

Fig. 149.



Sphenophyllum.

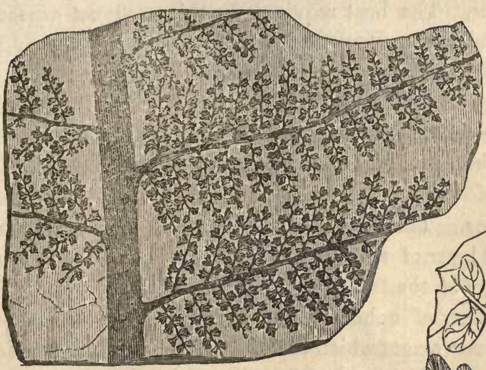


Sphenophyllum erosum.

Pecopteris (Alethropteris) lonchitica.

Alethropteris.

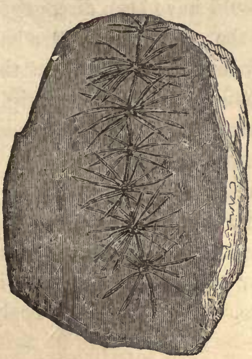
Fig. 150.



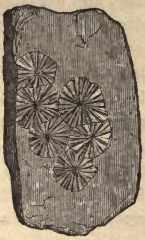
Sphenopteris allied to the microloba.

Alethropteris rugosa enlarged.

Neuropteris undescribed, South-western Virginia.



Asterophyllites equisetiformis



Annularia sphenophylloides.

Sphenophyllum emarginatum.

have probably been subjected to a temperature sufficient to dissipate their volatile matter. The heat required for this need not exceed 400° Fahr., especially if accompanied with the escape of steam: a degree of heat insufficient to produce a material change in the texture of the rocks themselves, or to destroy the plants imbedded therein. Or we believe it is more agreeable to all the facts now known to ascribe the cause of debituminization to heat disengaged by the collision of the masses when the upheaval of the coal measures took place. The excessive displacement of these rocks has affected every layer of the mass concerned. The obliteration of specific characters of the fronds of the ferns and other vegetable fossils show the effects of upheaval, and the sliding of the masses upon each other; a movement which could not take place without the development of heat. If heat had been propagated from below, from igneous masses, the lower rocks must have suffered a complete fusion before heat to a sufficient amount could have been disengaged to have effected the debituminization of the coal. Rocks are bad conductors of heat; hence the necessity for its generation in the midst of the masses themselves rather than in ascribing its origin to distant heated bodies beneath. Of course we except those cases where trap is found in the immediate vicinity of beds of coal.

In market coals are frequently distinguished from each other by the color of their ash; thus there are red and white ash coals; the former usually have the most clinker, and injure the grate more than the white ash. The white is firmer and less broken, and is regarded as the most valuable of the two. These remarks apply to the anthracites of Pennsylvania.

150. *Distribution.*—The British provinces, Nova Scotia, New Brunswick, and Newfoundland, have large areas underlaid by the Carboniferous System. In the United States the Alleghany coal field stretches through Pennsylvania, Maryland, Virginia, Tennessee, to Alabama, a distance of nearly 900 miles, and occupies in part a width of country about 200 miles. It is not to be understood that this is now a continuous bed: it is interrupted and broken by upheavals of the strata at a period intervening between the close of the Carboniferous and the beginning of the Triassic. The beds of Pennsylvania, however, are identical with many in Ohio, and hence were no doubt continuous deposits over wide areas. Illinois, Michigan, Iowa, Missouri, and Kansas possess large and important bituminous coal fields which are only slightly disturbed, while the anthracite coal fields of Pennsylvania are greatly disturbed by upheavals being uplifted into anticlinal and synclinal axes. It is strictly mountainous, the axis of crests running north 65° to 70° east.

151. *Recapitulation.*—We have said that the Carboniferous epoch is a stand-point from which we may survey the past and future. Let us pass in review some of the leading events and changes which had already transpired in the earth's history. Physically the earth, since sediments began to collect, had undergone great changes. The plains, valleys, and lower mountains had received thousands of feet of debris, and what was once a rough pinnacled surface of pyro-crystalline rocks is now covered with sediments evenly spread out, forming the foundation of plains and gently sloping hills, suitable for the plough and other implements of husbandry.

But the vegetable kingdom has kept pace with the physical. At first the sea only produced plants, all of which belonged to the lower organisms of the kingdom; now forests of pines, intermingling with palm-like sigillaria, equalling in size and height the largest of our trees, cover large areas. Among these dark green forests the ferns and fern-like plants, the lycopodiums, plants analogous to our ground pines, are the most conspicuous. Vegetation, to say the least, is rank, forming impenetrable jungles and thickets. We know not whether the mountains were clothed like the plains, but we find trunks of trees, stripped of their foliage, imbedded in the sandstones of this period, which must have floated down some rapid river, and finally with its still and gentle currents were borne out to sea, where, water-logged, they sank and were buried in sand or mud.

But what of the animal kingdom? here, too, we witness progress; the sea, however, is still the field in which life is strong: its fish of the higher grade verge upon reptilian forms; their teeth and scales belong to types of this class. They form as yet only two ranks, the ganoids and placoids; but they have reached their maximum of power, notwithstanding they came in late in the Silurian epoch. Hence we have the reign of fish extending only over two full epochs. No mammal, either of the land or sea, or an air-breathing thing, has yet appeared, except a feeble Saurian Telerpeton, and the more powerful Stagonolepsis, closely allied to the Teleosaur of the Jurassic, and the small Archegosaur of the Carboniferous age. But they scarcely represent power or rank, and they rather foreshadow the advent of this powerful race of the Jurassic era. But many forms have disappeared, or are about to disappear. The Trilobites no longer exist, and forms more like the present have taken their place. The Orthoceratites, which are *Cephalopods*,

and were the tyrants of the seas, in the Lower Silurian stage, have also become nearly extinct, and will soon be replaced by the *Belemnite* of the middle ages. So also wide gaps have been made in the Brachiopodian ranks, especially in the family of the Spirifers. These and analogous forms are about to be replaced by the Ostreas and Terebratulas, many species of which have continued to the present epoch. If the law of progress is well established, the death law is equally so; for not a Silurian species lives in the Carboniferous seas; yet, in all the millions which have perished, not a typical form has been lost, but new patterns, based on the same types, seem to have sprung out of the old.

152. If any epoch then in the earth's history is worthy of being distinguished above all others, it is the Carboniferous. This view is sustained by two considerations; it is the epoch when the most valuable of all materials, COAL, was deposited, and it furnishes during its existence a magnificent exhibition of a flora unsurpassed in splendor and beauty, as in extent, by all the epochs through which the earth has passed. During this epoch there seems to have been a greater uniformity of temperature and climate than had been witnessed in any former one. Of this we may be assured by the greater number of plants which belong to the same species in distant parts of the world. The coal plants, for example, of Europe do not differ materially from our own; many are identical species. In this particular, then, we have that kind of evidence which naturalists rely upon to prove similarity of conditions of distant and remote parts of the world.

But the importance of this epoch, in consequence of the inexhaustible masses of fuel which have been preserved in its rocks, cannot be over estimated.

Civilization, as we have said, is due in a great measure to the events of this remote period.

Before the highest order of our plants was created, before a warm-blooded animal came into existence, before there existed in creatures a single amiable instinct, we see a full provision in the economy of nature for the wants of a future age which no event foreshadowed, except it may have been in the immense store of fuel which belongs to this special epoch.

153. But there is another aspect under which we ought to regard the Carboniferous epoch, if we would fully understand its importance; it is its length, which, if measured by the depth

of its sediments, holds the first rank in point of duration. There is a fitness in this respect which adds immensely to the probability of the view we have taken, aside from the thickness of the sediments of this epoch. In all arrangements which bear the impress of *prospectiveness,* there is a consistency in *time* and *means,* to the *end* foreshadowed. There was to be laid up in store for future ages a stock of fuel for the nations, that the development of human power and greatness should not lack in the essential material necessary to carry out in full the design of their creation. Time, then, was necessary in these arrangements, and coal being of vegetable origin, the slow growth of centuries multiplied by centuries, would be only adequate to the production of matter for a single seam. But many seams were demanded, and hence the depth of the strata and the prolongation of the epoch.

154. The Carboniferous epoch then standing out in bold relief from all others which preceded it, and from those which succeed, has become like a beacon from which the geologist surveys those anterior changes which ushered it in, as well as the posterior ones which have followed. It witnessed the introduction of thousands of new forms belonging to the vegetable kingdom, as well as the introduction of new classes of animals, so that the aspect which it presented had no similarity to any which preceded.

The previous faunas and floras reach the commencement of this epoch, but do not enter it; and its own fauna and flora have nearly disappeared from the earth at its close. It is, therefore, a well defined epoch, having a beginning and ending, and we may say a middle term also, which marks its most distinguished and characteristic aspect. It is not then a sudden introduction of an epoch starting into life in its full development, but, like all others, it begins with an introduction of a minor importance with an exhibition of a few new classes which increase gradually, evolving continually new and striking phases as time rolls on, until we see, after the passage of ages, the full development of the characteristics which mark unmistakably an epoch entirely new in the world's history.

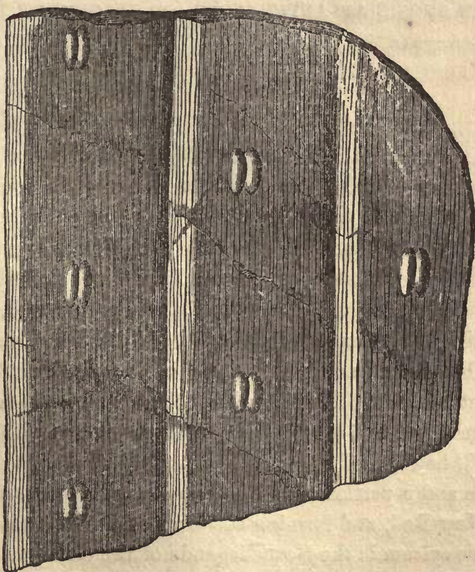
The history of the rise and fall of nations presents an analogous aspect, rising to their zenith and importance by successive steps, until finally the acme of power and rule is attained, when, by a series of declining ones, it merges itself into a new order of things

155. *Comparative View of the Devonian and Silurian Systems, Exhibiting their Relations to the Carboniferous as it Exists in Several States of the Union; the New York Series being taken as the Standard of Comparison.*

		New York.	*Pennsylvania.*	*S. W. Virginia.*	*Ohio.*	*Missouri.*
	31	. . . .	Coal measures.	——————	——————	——————
	30	. . . .	. . . .	. . . .	. . . .	Mt. Limest.
	29	Conglomerate ?	——————	. . . .	. . . .	. . . .
Devonian.	28	Cattskill group	——————	. . . .	. . . .	. . . .
	27	Portage and Chemung group	——————	. . . .	. . . .	——————
	26	Genesee slate	——————	. . . .	——————	. . . .
	25	Tully limestone	——————	. . . .	. . . .	. . . .
	24	Hamilton group	——————	. . . .	. . . .	——————
	23	Marcellus shale	——————	. . . . . .	——————	. . . .
	22	Corniferous limestone . . .	——————	. . . .	——————	. . . .
	21	Onondaga limestone	——————	. . . .	. . . .	——————
	20	Schoharie grit	——————	. . . .	. . . .	. . . .
	19	Cocktail grit	——————	. . . .	. . . .	. . . .
	18	Oriskany sandstone	——————	. . . .	. . . .	. . . .
Silurian.	17	Encrinal limestone	——————	. . . .	. . . .	. . . .
	16	Delthyris shaly limestone .	——————	. . . .	. . . .	——————
	15	Pentamerus limestone . . .	——————	. . . .	. . . .	. . . .
	14	Manlius water lime	——————	. . . .	. . . .	. . . .
	13	Onondaga salt group	. . . .	. . . .	. . . .	. . . .
	12	Niagara group	——————	——————	. . . .	. . . .
	11	Clinton group	——————	——————	——————	. . . .
	10	Medina sandstone	——————	——————	——————	. . . .
	9	Oneida conglomerate	——————	——————	——————	. . . . . .
	8	Lorraine shales	——————	——————	——————	——————
	7	Utica slate	——————	——————	——————	——————
	6	Trenton limestone	——————	——————	——————	——————
	5	Black River limestone . . .	——————	——————	——————	——————
	4	Bird's Eye limestone	——————	——————	——————	——————
	3	Chazy limestone	——————	——————	——————	——————
	2	Calciferous sandstone	——————	——————	——————	——————
	1	Potsdam sandstone	——————	——————	. . . .	. . . .

In explanation of the foregoing table it may be observed that the coal measures of Pennsylvania rest upon the Cattskill group, or upper rocks of the Devonian, the Carboniferous limestones being absent; while in South-Western Virginia they rest on the Upper Silurian. In Ohio the Cattskill group is absent, and hence the coal measures repose on other members of the Devonian. In Missouri, Kentucky, Tennessee, and Alabama the Lower Carboniferous limestone is present; and it rests on the rocks equivalent to the Chemung group in Missouri. In South-Western Virginia a series of salt-bearing rocks, with gypsum, belong to the Carboniferous series. The dotted lines represent the absent rocks.

Fig. 151.



Sigillaria biloba. (Sharp's Mountain.)

Fig. 152.

Dromatherium sylvestre.

CHAPTER XV.

PERMIAN SYSTEM—PHENOMENA MARKING THE CLOSE OF THE PALÆOZOIC DIVISION—AUTHOR OF THE SYSTEM, AND DERIVATION OF ITS NAME—CHANGES IN THE ORGANIC REMAINS—PERMIAN OF THE ATLANTIC SLOPE—DEVELOPMENT IN NORTH CAROLINA—SYSTEM DESCRIBED UNDER THE NAME CHATHAM SERIES, FOSSILS, ETC.

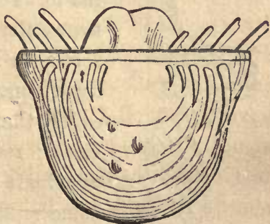
156. THE Palæozoic series closes with this system. Not because there is anything peculiar in the lithological character of its rocks, but because it was during the deposition of the strata which belong to it that the animals and plants which are closely related to those of the preceding epochs mostly disappear; while in the system which succeeds it all the Palæozoa are absent. In Europe, in 1846–7, about 166 species belonging to this system had been described, of which 148 are said to be characteristic of it, and 18 were found in the subjacent Palæozoic rocks. Its name is derived from the ancient government of Perm, Russia, where the series consists of sandstones, limestones, and conglomerates, &c. Phillips and Murchison, in England, had already proposed separating the magnesian limestone series and a portion of the sandstones of the superincumbent from the New Red, and forming therefrom a distinct system. The base of this system is the Rotheliegende of the Germans. It rests unconformably upon the Carboniferous. Hence, it appears that in Europe, after the close of the latter period, and after a state of comparative rest, the earth's crust was once more broken up by igneous forces, the Palæozoic rocks were tilted up, and hence all the subsequent rocks were deposited on their upturned edges.

From these physical movements we have reason to expect that changes equally great in the organic kingdoms must have followed, for it seems to be a law that terrestrial movements have resulted in bringing about essential changes in the distribution of water and other physical conditions which affect unfavorably life in the aggregate; for in the overlying deposits we miss the forms which are familiar to us, and find them replaced by new ones, which are fitted for the new conditions which have resulted from those changes. But species die out, and are replaced by new ones during periods of quietude, and even quite a number may survive a period of disturbance, and pass from one system to another.

This system, in Germany, is formed essentially of three members, the Rothetodteliegende, Zechstein, and Kupferschiefer, and in England by the Lower New Red Sandstone and Magnesian Limestone. In Russia there are also beds of limestone, which have been identified with the Zechstein and Magnesian limestone, and which are also surmounted by marls, spotted sandstones, and conglomerates. In all the countries of Europe the foregoing members are quite similar lithologically; besides, they are connected together by a similarity of fossils.

157. There are many important changes in the fossils of this era which should be noticed. Taken as classes the Brachiopods have diminished considerably; but there are still remaining in the Permian 30 species at least, of which 10 are common to the carboniferous; that is, about one-third bebelong to the latter. The most common Brachiopod is the Productus horridus, fig. 153.

Fig. 153.



Productus horridus.

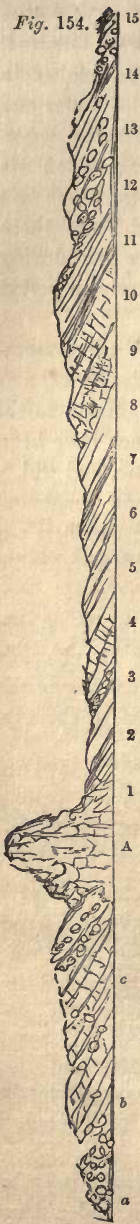
The Gasteropods and Cephalopods have both greatly diminished in numbers. Goniatites, Nautili, and Orthoceratites are almost all unknown in the Permian.

The Crustaceans are represented by the genus Limulus. The fishes are peculiar to the system.

In Russia the limestones, in England the Dolomitic conglomerate, and in Germany the Kupferschiefer, contain bones of Thecodont Saurians.

There are two extensive areas over which the Permian is probably spread in the United States, the Atlantic slope, and a large

Fig. 154.



portion of the Western States and Territories. The lithological characters are quite different in these two sections of the Union. We shall select only a few localities for the illustration of this series. Greenfield, Mass., and the adjacent country in the neighborhood of Turner's Falls, give us an interesting series, the lower part of which we place in the Permian.

158. The Greenfield Section embraces the following beds:—Fig. 154, a coarse red conglomerate: *b*, red sandstone with a few pebbles; *c*, gray brecciated conglomerate; A, trap. This series, from *a* to A, is about 2200 feet. The trap divides the sandstone, and we find on the east side of it 1, red shale and red sandstone, which are impressed with the earliest footprints which hitherto have been regarded as the prints of birds' feet. 2. Brecciated conglomerate. 3 and 4. Red sandstone alternating with pebbly beds. 5. Shaly sandstone with footprints. 6. Red sandstone. 7. A dark-colored shale with footprints. 8 and 9. Crushed beds consisting of fine-grained calcareous sandstones. 10. Gray sandstone and dark-colored flags. 11. Slates. 12. Coarse conglomerates. 13. Dark-colored flags with footprints, at a place known as the Horse Race on the Connecticut River. 14 and 15. Slates alternating with pebbly beds. They form the upper part of this series. The first 2200 feet only are regarded as Permian. The casts of vegetable stems agree in character with the lowest sandstones in North Carolina.

159. The following section, which is only referred to, is similar to the preceding in part. It illustrates the beds which we have called the Chatham series, in North Carolina. It is the most southerly series upon the Atlantic slope. In the ascending order, there are conglomerates from 50 to 60 feet thick; red and brown sandstones and marls, which terminate in gray sandstones, which sometimes become reddish after long exposure to the air. We regard the Lower Red sandstones as equivalent to the German Rothetodteliegende. Upon this sandstone repose the bituminous slates, coal, and black-band, succeeded by gray, sandy shales, finely rippled, and marked also with insect trails, followed by repetitions of bituminous shale, coal, black-band, and fire-clay. Then follow thin beds of greenish.

calcareous shales, containing magnesia, alternating, repeatedly, with bituminous shales. The whole thickness of these shales is at least 600 feet. Gray sandstone follows, which is often finely rippled; and then, beds of conglomerate, alternating with bluish, non-bituminous shale, with lignite, and stems of silicified wood, together with greenish, sandy, and gray shales and sandstone, with cycads, gray sandstone, and mottled or spotted sandstones and marl. Near the top of the series, in many places, there is a compact gray magnesian limestone, which contains a few fossils. The Triassic series is, probably, unconformable to the Chatham series. The upper part is often highly charged with pebbles; and on the Dan river, it is coarsely brecciated. These conglomerates are, undoubtedly, parallel with those on the Connecticut river, at, or near the Horse Race.

160. *Fossils of the Lower Red Sandstone Shales, Black-band, &c., Fig.* 155.—Chondrites interruptus. In the upper part, below the bituminous shales, we have found a biconcave vertebra, and other bones, supposed to belong to a Thecodont Saurian. (Fig. 160).

Fossils of the Bituminous Shales, Coal, Black-band, Ore, &c.—The most interesting, is the jaw of an insectivorous mammal, fig. 152, twice the natural size—the Dromatherium sylvestre. It is the lower jaw, and belonged to the oldest known mammal. The next most interesting fossil, is the Rutiodon Carolinensis, fig. 157; *a.* a premaxillary bone; *b.* nostrils. The premaxillary is subcylindrical, and consists of one solid piece. The original is 30 inches in length. The teeth of this Saurian are all fluted more or less distinctly; in which respect it differs from the Clepsisaurus of Lea, fig. 158. 1, 2, 3, 4, 5, 6, 7, 8, represent the teeth of the Clepsisaurus. 7 and 8, are transverse sections.

The upper jaw of the Rutiodon is nearly cylindrical, as it is prolonged in front of the nostrils, which are just anterior to the large eye-sockets, and descend vertically, like the blow-holes of a cetacean. Notwithstanding this prolongation of the snout, and its spoon-like enlargement at its end, it differs materially from the Teleosaurus of the Lias. (Fig. 158; 11, 12, different forms of the teeth of the Palæosaurus.)

The Chatham series, and indeed, the lower beds of the entire formation, which ocupy the Atlantic slope, rests upon either the pyrocrystalline rocks, or the slates of the Taconic System. In North Carolina, beds of porphyry support the lower red sandstone, and

hence we are deprived of a clue to the age of the series, by the absence of all the systems between the Taconic and Carboniferous. In the Western States and Territories, however, the so-called Permian, first recognised, we believe, by Mr. Meek, succeeds the Carboniferous, with which it is also conformable; and many Carboniferous species are intermingled with those fossils, which are supposed to be Permian species. There is, therefore, reason for raising the question, whether the upper beds, which are regarded as Permian, may not be classed with the Carboniferous.

161. *Distribution.*—Upon the Atlantic slope, especially in North Carolina, the evidence of the Permian age rests on the presence of Thecodont Saurians, which in England are referred, by the best geologists, to this system. In North Carolina, this view is strengthened, by the presence of the Trias, which is superimposed upon the beds which contain the Saurians in question. There would have been less objection to this view, no doubt, had the Dromatherium been found in the Trias, or in the rocks of the Mesozoic age. Assuming the observations of many geologists respecting the Permian elsewhere in this country as correct, it is evident this system occupies a wide area westward. It exists in Illinois, Kansas, Nebraska, at the Black Hills, Missouri, and New Mexico. Its boundaries, however, are undetermined.

Labyrinthodont of the Trias restored, with its foot-prints.

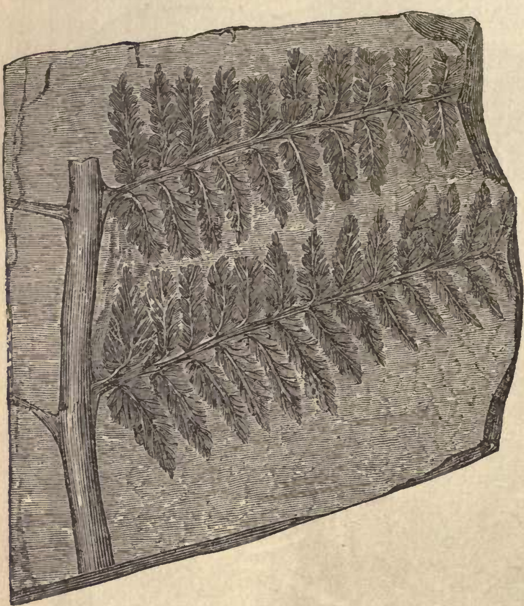
Fig. 155.

PLANTS OF THE CHATHAM SERIES.

Chondrites interruptus.

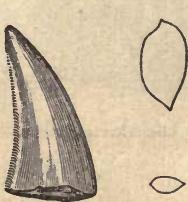
Fig. 156.

PLANTS OF THE CHATHAM SERIES.



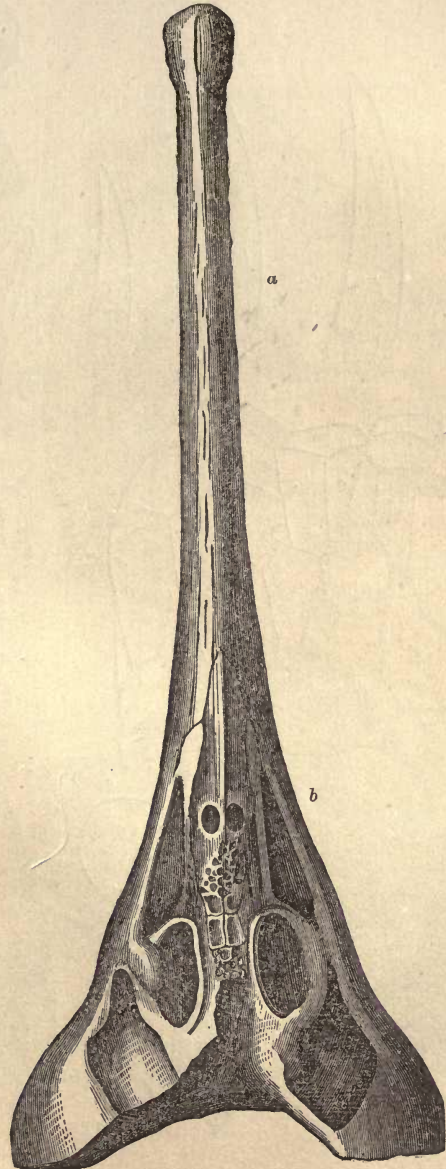
Leaflet enlarged.

Sphenopteris Egyptiaca.



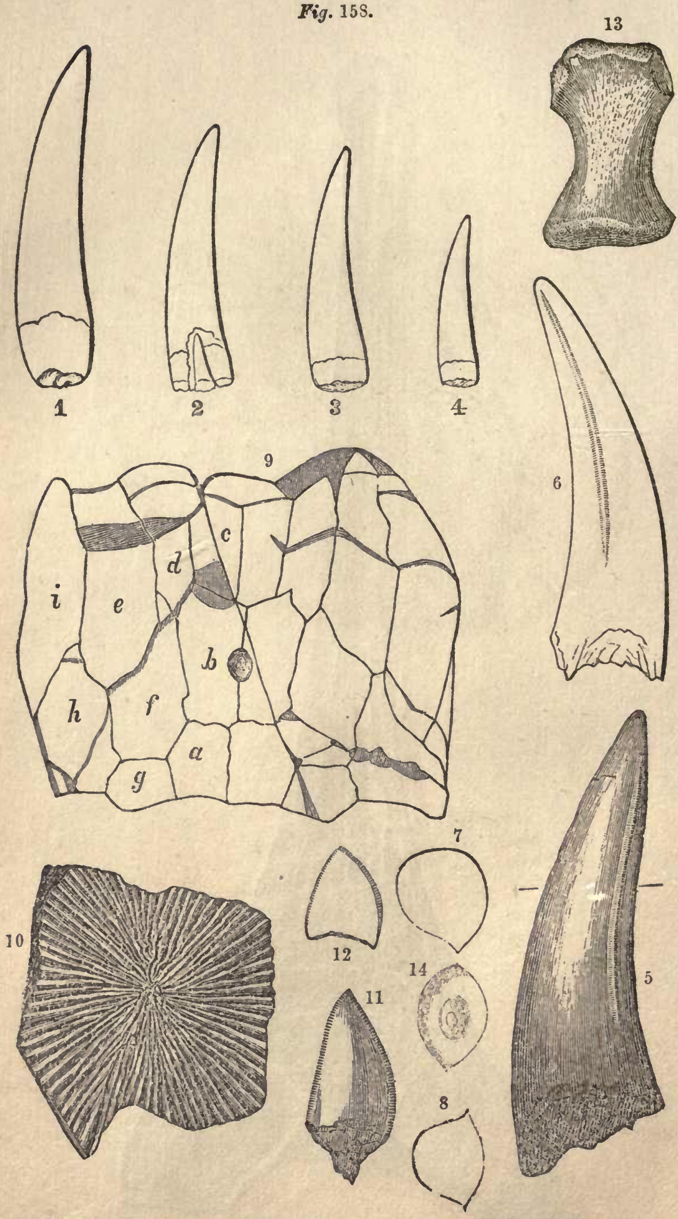
Saurian Teeth of the Bituminous Slates of the Chatham Series, N. C. (Twice natural size.)

Fig. 157.



Rutiodon Carolinensis. *a.* Premaxillary bone. *b.* Nostrils.

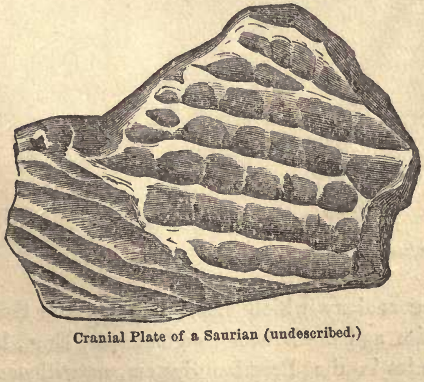
Fig. 158.



1, 2, 3, 4, 5, 6, 7, 8. Teeth and sections of the teeth of the Clepsisaurus Pennsylvanicus. 9. Posterior of the skull of the Dictyocephalus elegans, Leidy. *a*. Occipitals. *b*. Parietals. *c*. Frontals. *d*. Post Frontals. *e*. Post orbitals. *f*. Squamous. *g*. Mastoids. *h*. Typanios. *i*. Zygomatics. 10. Cranial Plate of the Dictyocephalus. 11 and 12. Teeth of a Palæosaurus? 13. Phalange of the Foot. 14. Tooth of a Pycnodont.

Fig. 159.

1. Dermal Plate of a Saurian. (Natural size.)

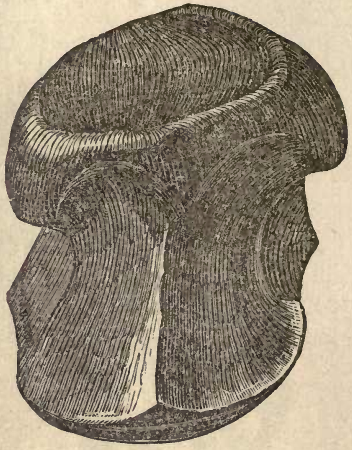


Cranial Plate of a Saurian (undescribed.)

Cranial and dermal plates of the kind represented above have been found only in the upper part of the lower sandstone.

Fig. 160.

SAURIANS OF THE CHATHAM SERIES.



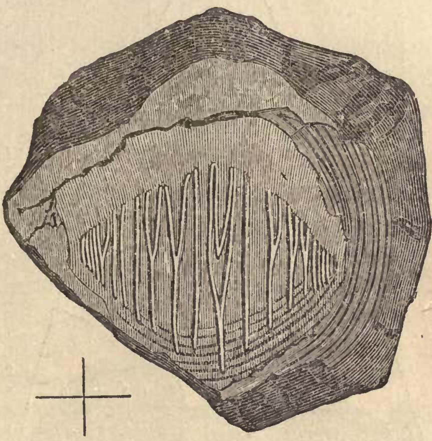
2. Biconcave Vertebra of the Clepsisaurus.

1. Double-headed Rib of the Rutiodon.

The strong analogy which exists between the Saurians of the Chatham series and the Bristol conglomerate, Eng., has led us to place the series in the Permian System, notwithstanding the existence of the mammal already referred to. The vertebræ are not only biconcave, but in other important respects resemble those of the Thecodonts of the English beds which are regarded as Permian.

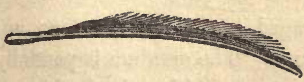
Fig. 161.

FISH REMAINS OF THE CHATHAM SERIES.



Rabdiolepis speciosus.

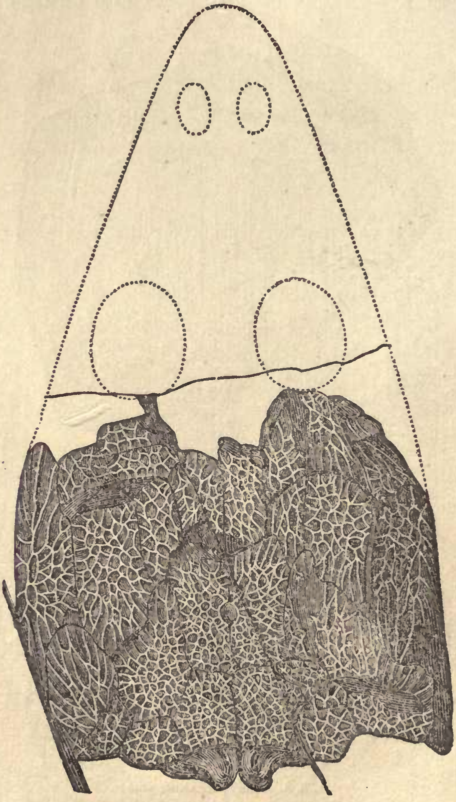
1, 2, 3. Amblypterus ornatus?



Stile of the fin of a fish.

Fig. 162.

LABYRINTHODONT OF THE CHATHAM SERIES.



Head of the Dictyocephalus elegans (Leidy).

This skull belonged to a Labyrinthodont, and is probably allied to the Archegosaurus. The cranium is partially restored; the posterior part is complete, exhibiting the double condyles of this order of Saurians. Fig. 158—9. The plates are designated. The restoration was made by Prof. Leidy.

CHAPTER XVI.

TRIASSIC SYSTEM—DIVIDED INTO THREE MEMBERS—BASE OF THE MESOZOIC DIVISION—MINERAL CONTENTS—ITS FAUNA AND FLORA—IMPRINTS OF THE FEET OF BIRDS AND BATRACHIANS.

162. THIS series is composed of three distinct members: the Bunter sandstone, the inferior, the Muschelkalk, the middle, and the Keuper, the superior member. The lower and upper are shore deposits; the middle, a deep marine deposit, which is, no doubt, partly a mechanical, and partly a chemical formation. It is frequently absent, as in England and America. It is rich in molluscs, and hence its name.

Although this system is the base of the Mesozoic division, it is still conformable to the Permian, presenting, in this particular, an anomaly, when the relative position of the latter is considered; for this system, the Permian, is discordant to the Carboniferous, upon which it rests. It seems, therefore, there is a break in the series at the wrong place; it should have been at the commencement of the Mesozoic division, the base of the Trias.

The progress of discovery has brought to our knowledge much that tends to obliterate the strong lines of demarkation between the Palæozoic and Mesozoic divisions. Quite a number of Palæozoic genera pass up, and are associated with those of the middle division. Still, there are grounds for regarding the Trias as indicative of a new era, by the introduction of a new class of vertebrates, the birds; such an event certainly should be marked in our subdivisions of the strata.

163. This system contains beds of rock-salt, brine springs, and gypsum, and hence has been called the *Saliferous System*, and hence, too, is important for its valuable mineral contents.

But its fauna and flora confer a special interest upon the system. The animals are peculiar; the Saurians, for example, are Labyrinthodonts, which partake strongly of the Batrachian type. In

Europe, a single mammal has been found, the Microlestes, in its upper member the Keuper. But our interest in the series is greatly heightened by the evidence that birds appeared upon this planet, for the first time during this epoch. The inference to this effect, is based on foot-prints upon the strata, which possess all the characteristics of this class of bipeds—a foot-print, provided with the three toes in front, and the requisite number of joints to each toe. Some years ago, the enormous size of the foot-prints, created some doubt of their having been made by birds; but discoveries of the remains of birds of gigantic stature, in New Zealand, have dispelled those doubts. Fig. 163, imprints of birds' feet, in the shale of Turner's Falls, Mass. In similar shales, and near the same horizon, fish remains are numerous. Fig. 164 is the Eurinotus ceratocephalus; it is an unique specimen, exhibiting appendages upon the front part of the head. It is associated with the genus Ischypterus, which occurs at Sunderland, Mass. At Boonton, N. Y., similar beds of shale contain fish remains, of the same species as those of Turner's Falls and Sunderland. In North Carolina, fish remains of the same family, occur in the upper sandstone.

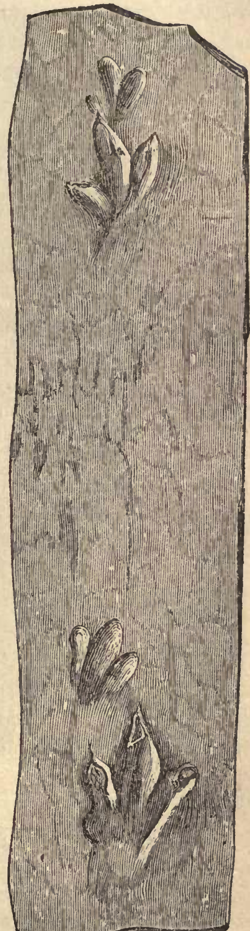
164. The lithological characters of the Trias are exceedingly varied. Red sandstones and shales, often mottled, prevail, but gray and red conglomerates, red shales, calcareous shales, of a reddish tint, bituminous shales, of a black color; also, black, purple, green, and spotted shales, which are not bituminous or common. As in other systems, its base is a conglomerate. Near Turner's Falls, in the vicinity of Greenfield, the conglomerate is gray, and numerous beds of different lithological characters succeed, in the order represented in fig. 154. This section was referred to in the notice of the Permian system, but is more particularly described in this place. Thus, from *a* to A, comglomerates, red sandstone, usually coarse, and often pebbly, embracing a thickness of over 2000 feet.

165. A. Heavy beds of greenstone which divide the formation on the east side of the greenstone. 1. Red shales. 2. Conglomerate traversed by a trap dyke. 3. Red sandstone. 4. Red sandstone alternating with pebbly beds. 5. Shaly sandstone with footprints of birds. 6. Red sandstone. 7. Thin shaly dark-colored beds with footprints. 8. Broken and crushed beds of fine-grained calcareous sandstone. 9. Fine-grained calcareous sandstone. 10. Gray sandstone and dark-colored flags. 11. Slates. 12. Coarse conglomerate. 13. Gray and dark-colored flags and slate with footprints. 14. Slates, alternating with pebbly beds—

Fig. 163.

IMPRINTS OF FEET.

Imprints of the Feet of Birds.



Imprints of the Feet of a Batrachian.

Fig. 164.

FISH REMAINS.

1. Eurinotus ceratocephalus.

some of which are coarse. This series embraces a thickness of not less than 5000 feet.

The materials composing these beds are derived from the neighboring talco-micaceous slates and granites. In the conglomerates large fragments of mica slate are common—exceeding a foot in diameter—they are both angular and rounded.

We may recognise two movements while the foregoing sediments were being deposited; the first, immediately preceding the deposit of the gray conglomerate, No. 1; the second, towards the close of the period, at No. 12, and which seems to have been frequently repeated until its close.

166. The Triassic series are exposed in Wake and Orange counties, N. C. The railroad leading from Raleigh to Hillsborough passes over them nearly at right angles to the dip of their beds. At Morrisville, 12 miles from Raleigh, the lower conglomerates are visible—and in proceeding to Durham Station the dip may be seen at numerous places, inclining at about an angle of 10° to the north-west. This being the regular dip of the series here, we conclude that there is an unconformability between these beds and those which belong to coal measures of Deep river, for there the dip is south and south-west. It is also fully ascertained that the latter are absent, and the former repose on the older slates.

This series is remarkably well developed on the North Pennsylvania Railroad, beginning near Fort Washington Station, Pa. This road crosses the entire series. At Gwynedd Station, the tunnel cuts through a part which corresponds with the Phoenixville Station. Several beds of black and green slates frequently occur, as partings between heavy beds of a tough, brownish, granular sandstone. This part has been disturbed, and seams of calcspar are common in the tunnel, in which, also, may be seen solid bitumen, or coal. A Posidonia occurs at Gwynedd, and frequently, worm-tracks, and rarely a calamite. After passing the tunnel, the rock is mostly a shaly sandstone, with fucoids. This belt, between Gwynedd and the next station north, corresponds to one near Greenfield, Mass.

167. The most interesting relics of the Trias, as already stated, are the imprints of the feet of birds, inasmuch as they furnish indications that the earliest existence of this class of animals is found in this formation. The imprints already referred to were made by a biped. The substance of the rock was soft at the time they were made, and hence there is a want of sharpness in the outline of the foot. Birds of gigantic size strode along the beaches of olden time, if the imprints of their feet furnish a criterion of size and weight. For example, there are footmarks in the Trias of Con-

necticut, which measure seventeen inches from the heel to the point of the middle toe. Others are small, and resemble the imprints of the feet of small shore-birds, not unlike those of the present day.

Fig. 165.

Trails of Insects.

But imprints of various kinds are common upon the fine sandy deposits; even insects have left their trails. Whoever is at pains to observe the surfaces of fine plastic clays after a shower will find trails of larva, and also of perfect insects, around the parts of water which are left standing by roadsides and in undisturbed fields. Fig. 165 shows the trail of what appears to have been made by larva of some dipterous insect, preserving also the impression of raindrops. (See also pl. vi. American Geology, figs. 105, 106, 107, 108). So also in the ancient Trias, at Turner's Falls, furnish trails of insects, of which fig. 109, of the same work, is an example.

168. The Mollusca (Entomostraceans) of the Triassic sandstones are by no means numerous. The Posidonia (Estheria) minuta is regarded as a characteristic fossil of this series, and occurs in North Carolina. Fig. 166 represents several species of forms allied to the Posidonia. In North Carolina, and also in Massachusetts, the most common fossils belong to the vegetable kingdom. Of these an interesting family of plants are well known, as *Cycades,* which are among the vegetable products of Australia.

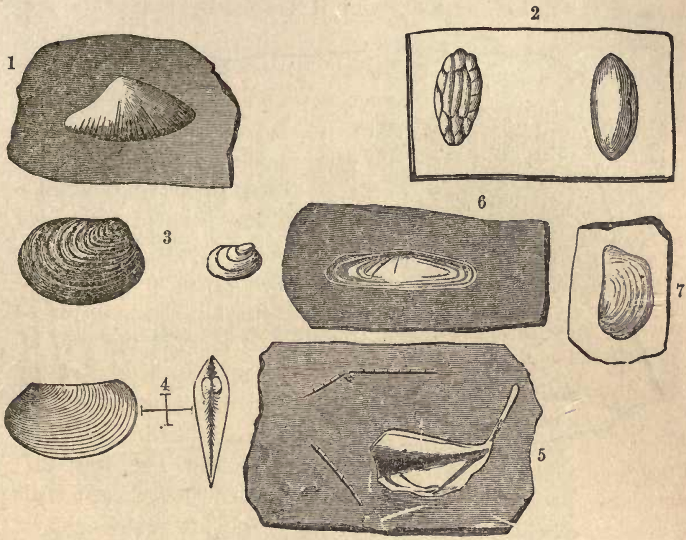
The plants represented in the plates 168, 169, are regarded by Professor Heer as indicative of the Keuper, the upper mass or division of the Trias, and they are particularly noted as being infra Liassic, which is a very important fact, inasmuch as they belong to the superior mass, and are widely separated from the Chatham series by sandstones and conglomerates. These facts give character to the conclusion that the Chatham series represent a part of the Permian system.*

Other plants, belonging to the Lepidodendron and ancient conifers, are not uncommon in the plant-beds of the Trias, and a characteristic one is probably (fig. 172) an Albertia latifolia?

* See Note B, page 280.

Fig. 166.

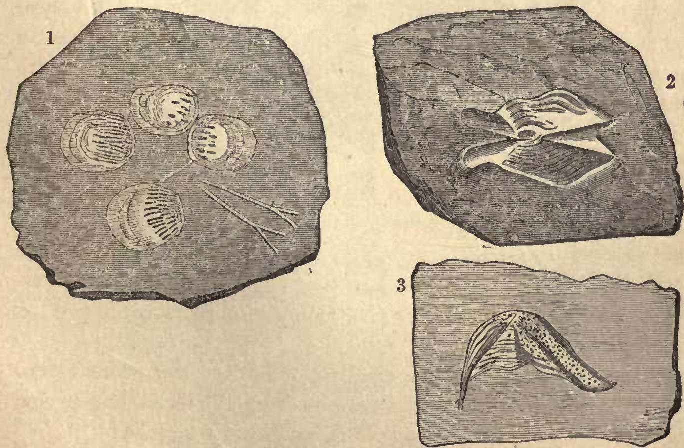
ENTOMOSTRACEANS OF THE BUNTER SANDSTONE.



1. Myopia pekinensis. 2. Cypris. 6. Myopia curta. 4, 3. Posidonia (Estheria). 5. Stylorhynchus unsymmetricus. 7. Posidonopia rhomboidea.

Fig. 167.

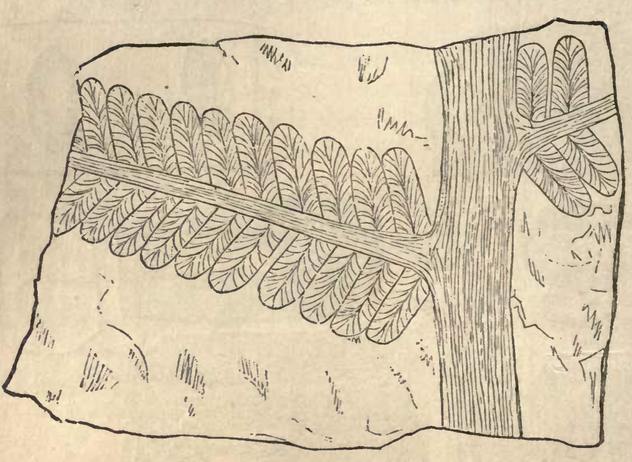
FISH REMAINS.



1. Scales of the Rabdiolepis elegans, E. 2. Cranial bone. 3. Bone of the Rabdiolepis.

Fig. 168.

PLANTS OF THE TRIAS.



Neuropteris ellingtonensis.

Strangerites obliquus, E.

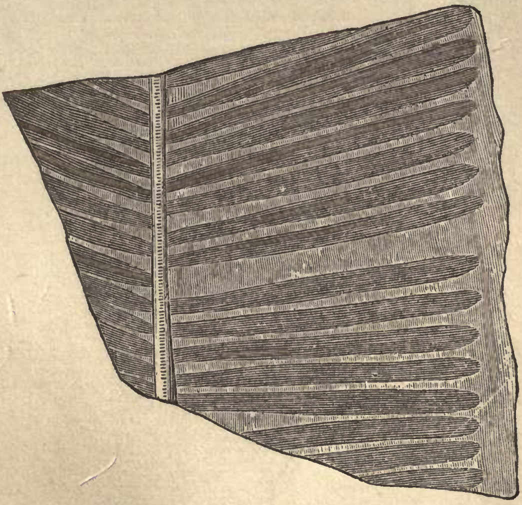
Pterozamites obtusus, E.

Fig. 169.

PLANTS OF THE TRIAS.

Gutbieria Carolinensis, E.

Pterozamites obtusifolius, E.



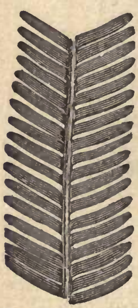
Pterozamites spatulatus, E.

There are three important localities which furnish plants:—1. The quarry of Mr. House, of Haywood, situated about one mile from the village, upon the Haw River. 2. Lockville, formerly known as Jones's Falls, upon Deep River. 3. Ellington's, about five miles west from Lockville. The slates which contain them are usually dark colored, but not bituminous, though at Ellington's there is a seam of bituminous coal about two inches thick. These beds are immediately above beds of conglomerates, or else interlaminated with them. No animal remains, as fish scales, the estheria, or mollusks, have yet been found associated with them. Similar beds occur only at other points in the valley of Deep River, far above the bituminous slates, which furnish coal, and the remains of the Clepsisaurus, Rutiodon, &c.

Fig. 170.

PLANTS OF THE TRIAS.

Pterozamites linearis. E.



Pterozamites gracilis. E.

Pterozamites pectinatus, E.

Fig. 171.

PLANTS OF THE TRIAS.

Taxodites brevifolia, E.

Walchia variabilis. E.

Lepidodendron.

Taxodites gracilis. (Enlarged one-half.)

Fig. 172.

PLANTS OF THE TRIAS.

Albertia latifolia?

Fossil ferns are equally common, and sometimes they are found with fruit dots.

The epoch of the New Red Sandstone, or Trias, terminated in numerous disturbances of the earth's crust, for in Europe as well as in this country the fine sediments are interlaminated with coarse gravels, and frequently these beds contain large blocks of angular rocks, or those which are only partially rounded. Beds of conglomerate, made up of stones of the size used in paving streets, are by no means uncommon. There is therefore strong evidence that the oscillations of the earth's crust were of common occurrence, and led to a frequent change of level, and of course to a change in the direction of rivers and currents.

169. In connection with these physical changes the student will find the formation traversed by the pyroplastic rocks, greenstones, porphyries, and amygdaloids. Igneous outbursts were therefore common, and were probably the direct causes which produced the oscillations of the earth's crust, already referred to.

We therefore regard the Triassic epoch as one distinguished for the phenomena we have referred to. The formation of rock salt and gypsum were undoubtedly connected with these disturbances, giving origin to extensive isolated sheets of water, where evaporation of sea-water furnished beds of salt and gypsum.

170. At the close of the Triassic we find several genera of fossils which are common to the Palæozoic division; for example: the Cyrtoceras, Orthoceras, Goniatites, Murchisonia, Euomphalus, and Porcelia. In the Trias we find the following genera, which make their first appearance here, and finally become common in the Mesozoic division, viz.: Ammonites, Belemnites, Cardita, Trigonia, Ostrea, and Plicatula.

The association, then, of the older genera with the newer ones, which soon prevail to a great extent in the Mesozoic division, serves to efface the sharper lines of distinction which had hitherto prevailed respecting these two great periods in the earth's history.*

* The Clathropteris rectiusculus, H., discovered by Prof. Hitchcock at East Hampton, towards the upper part of this series, does not prove that the part in which it was found belongs to the Jurassic; it differing specifically from the Jurassic species of Europe; inasmuch, too, as the genus belongs also to the Triassic system. Hence it would be as consistent to claim this plant for the latter as for the former system.

CHAPTER XVII.

JURASSIC SYSTEM—IMPERFECTLY REPRESENTED IN THIS COUNTRY—ITS POSITION ON THE CONTINENT OF EUROPE—ITS SAURIAN REMAINS—CHARACTER OF THE SEDIMENTS—DIVIDED INTO FIVE STAGES—THE LIAS HAS THREE GROUPS—THE WEALDEN CLOSES THE EPOCH.

171. So little is known of the Jurassic system in this country, that we prefer to describe very briefly the European series, as this epoch, as we find it here, is only imperfectly represented. In certain points of view, it is interesting, as well as important. It occupies a central position on the Continent of Europe, being well developed in the Jura Mountains, lying between France and Switzerland; especially the Liassic stage, which is regarded as the argillaceous base of the system.

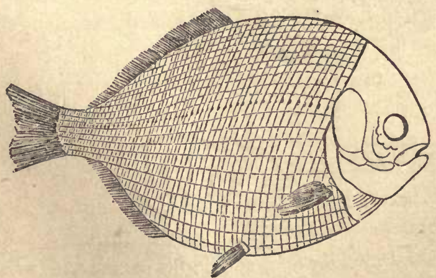
It is in this system, that Saurians attained a maximum development of this class of vertebrates; they were both numerous, and of immense size. Two very remarkable genera have been described in almost every treatise upon geology, viz.: the Icthyosaurus, and Plesiosaurus; the former is distinguished by a short, and the latter by a long neck. These reptiles were aquatic or marine, and were furnished with paddles of great power, for moving swiftly through the water. The eyes of the Icthyosaurus were large, and furnished with peculiar envelopes, or a special apparatus, which enabled them to adapt the vision to the distance of the object it wished to see. The Teleosaurus, another genus belonging to this epoch, was furnished with legs, instead of paddles, and in its general appearance, resembled the Gavial of the Ganges. It was in this epoch, also, that *flying lizards*, or *Pterodactyles*, seem to have been common, and to have contributed, by their organization and habits, to its singularity. In the organization of the reptiles of this epoch, it is easy to recognise in the Saurian type, the bird, fish, and cetacean.

The sediments of this epoch are fine, and well adapted to the preservation of fossils; and to this, we may attribute much of the exact knowledge we have obtained of the peculiar animals, and of their organization. Frequently, their skeletons are entire, or their parts so closely united, that it has not been difficult to restore their exact forms.

172. The Jurassic system has been subdivided into five stages: the Lias, Lower Oolite, Oxfordian, Upper Oolite, and the Wealden series. The whole series, in Europe, has a thickness of about 1030 feet.

The Lias is divided into three groups: the Lias Inferior, the Middle and Upper Lias. The passage from the New Red to the Lower Lias, is quite distinct. The latter consists of a fine white, micaceous sandstone, which often abounds in the remains of fishes; hence, it is blackened by animal matter, in the form of bitumen, and though the stratum is thin, it is recognisable over large territories. The Gryphea arcuata, fig. 174, 2, is one of the characteristic fossils. The Middle Lias, is a blue argillaceous limestone, often striped, and abounds with fossils, as the Spirifers, Pentacrinites, Pectens, Ammonites, and Fish; among which are recognised the genus Tetragonolepis, fig. 173, and an Ichthyodolerite of the genus Hybodus, fig. 194, 1. The Upper Lias consists of a dark-colored shale, particularly at Whitby, in England, and has been employed in the manufacture of alum.

Fig. 173.



Tetragonolepis.

194—1.

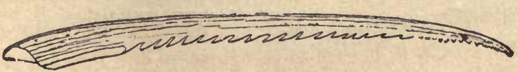
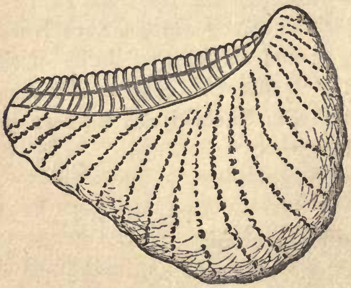


Fig. 174.

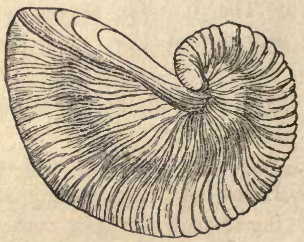
JURASSIC FOSSILS.

Gryphea pitcheri. Pyramid Mount.

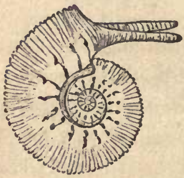
Ostrea marshii. Middle Oolite.



Trigonia.



Gryphea arcuata.



Ammonites jason.

Ancyloceras matheroniensis.

The Lower Oolite consists of alternating masses, or bands of limestones and clays. The particles forming the limestone, have the appearance not unlike the roe of fish, and hence the name *Oolite*. The Lower Oolite contains good building materials, and some inferior iron ores. This group is made up, in England, of *Inferior Oolite*, *Fuller's earth*, *Stonesfield slate*, *Bradford clay*, *Great Oolite*, *Forrest marble*, and *Cornbrash*.

Fig. 175.

Section Black Hills of Nebraska.

The group of Middle Oolite consists of five members: Kelloway rock, Oxford clay, lower calcareous grit, coral rag, and upper calcareous grit. The group contains Gryphea dilatata Ammonites jason. The Upper Oolites consist of Kimmeridge clay, Portland sand, and Portland stone.

The Wealden series brings the Jurassic system to a close. It is mostly a fresh water deposit, and is more fully developed in England than on the Continent. It consists of the Purbeck beds, Hastings sand, and the Weald clay. The fossils of this period are Unios, Cythere, and gigantic bones, belonging to an herbivorous land reptile, the Iguanodon, whose remains are also associated with an enormous carnivorous reptile, the Megalosaurus. The beds which are described in the preceding paragraphs, as forming the Wealden, are now referred, by several accomplished geologists, to the Lower Cretaceous; and it should be observed, that Prof. Leidy has recognised fossils in this group, which indicate the existence of the Wealden in Nebraska

The Jurassic system is not represented in this country by the presence of all the European members, though, in the far West, future investigations may prove that it is as fully developed as in the chain of the Jura.

The annexed section, fig. 175, is designed to show its relations, as it exists in the region of the Black Hills of Nebraska.

173. *Black Hills of Nebraska.*—Thus, 1. Granite nucleus, around

which the sediments have been deposited. 2. Metamorphic sediments, probably the Taconic system. 3. Potsdam sandstone, the only visible member of the Silurian system, and resting, unconformably, upon the Taconic series. 4. Carboniferous system, consisting of gray limestones and reddish grits. 5. Permian system. 6. Jurassic, consisting mainly of the Liassic stage. 7. Cretaceous. The Liassic series of this locality, consist of shaly beds of dark brown, and also yellowish sandstones, containing Belemnites, Pentacrinites, an Avicula, and an Arca, of Jurassic types.

The vegetable fossils of the Jurassic system, consist of Zamias and Cycadeas, resembling those which illustrate the New Red Sandstone of the preceding chapter.

174. *Distribution of the Jurassic System.*—The geographical area occupied by this system is not determined. It is, however, supposed to extend along the eastern slope of the Rocky Mountains, from the northern part of the British possessions in America, to New Mexico. It has also been recognised upon the head waters of the Yellowstone.

It is unknown upon the Atlantic slope; at least the evidence of its existence is not reliable.

Liassic Fauna and Flora rest red.

1. Plesiosaurus. 2. Ichthyosau us. 3, 5. Pterodactyle. 4. Cycad, &c.

CHAPTER XVIII.

CRETACEOUS SYSTEM—CHARACTERISTICS OF THE MESOZOIC DIVISION—DERIVATION OF THE NAME CRETACEOUS—LOWER DIVISION—THE GREEN-SAND LITHOLOGICAL CHARACTERS—FOSSILS OF THE GREEN-SAND.

175. The Mesozoic, which closes with this system, presents such peculiar aspects that its separation from the Palæozoic and Cainozoic was justifiable. This separation is based upon its flora and fauna, particularly the latter. At this day it is safe to assume that this division is sufficiently examined to assure us that we know its leading characteristics, which may be summed up in a few words. In its early stages reptilian forms of life were its most striking features. They stood out in such bold relief that they have been called the master existences of that age. We may refer to the Enaliosaurs of the Lias, and the Labyrinthodonts of the Trias. These, however, have all passed away, with the massive Megalosaurs and Iguanodon of a later period in this division of geologic time. But this division is also noted for the absence of mammals, excepting those which are of small dimensions. This, we say, must be received as a striking fact, not resting on conjecture, for reliable observations establish the abundance of reptiles, fish, and mollusks of forms peculiar to this period, while the mammals, if they had occupied a prominent rank in this ancient fauna, would have been also brought to light. It is true, that within the last eighteen months quite an addition has been made to the list of small mammals, no less than fourteen species having been added from the Purbeck beds of England, some of which are closely allied to the Marsupials, which occupy a low grade in this class. This is a significant fact in itself.

These, however, dwindle into insignificance, when compared with the hosts of marine and land reptiles, which were truly the master vertebrates of this epoch. With this division, too, we find one of the ranks of fish—the *Ganoids*—diminishing in importance near

its close. While, at the same time, the Ctenoids and Cycloids, two new classes, begin their existence, which are destined to fill a wide space in our own time. In the last series of the Mesozoic age the cretaceous rocks, the dying out or extinction of many races which had before been strong and powerful, the introduction or creation of classes destined to multiply upon the earth, to make up in numbers for the lack in force and individual strength, are great and significant facts of the period. Dynasties come to a close with the cretaceous, and dynasties begin; but they simply foreshadow their reign during the last third of the cretaceous system. We reach the same general results from a consideration of the vegetable kingdom. It is only at the close of this system that dicotyledonous trees, those which bear our favorite fruits and flowers, begin to make their appearance. They were created almost contemporaneously with the Ctenoids and Cycloids, the great classes from which we cull the favorite fish for our tables. Surely, such facts are not to be ranked as accidents.

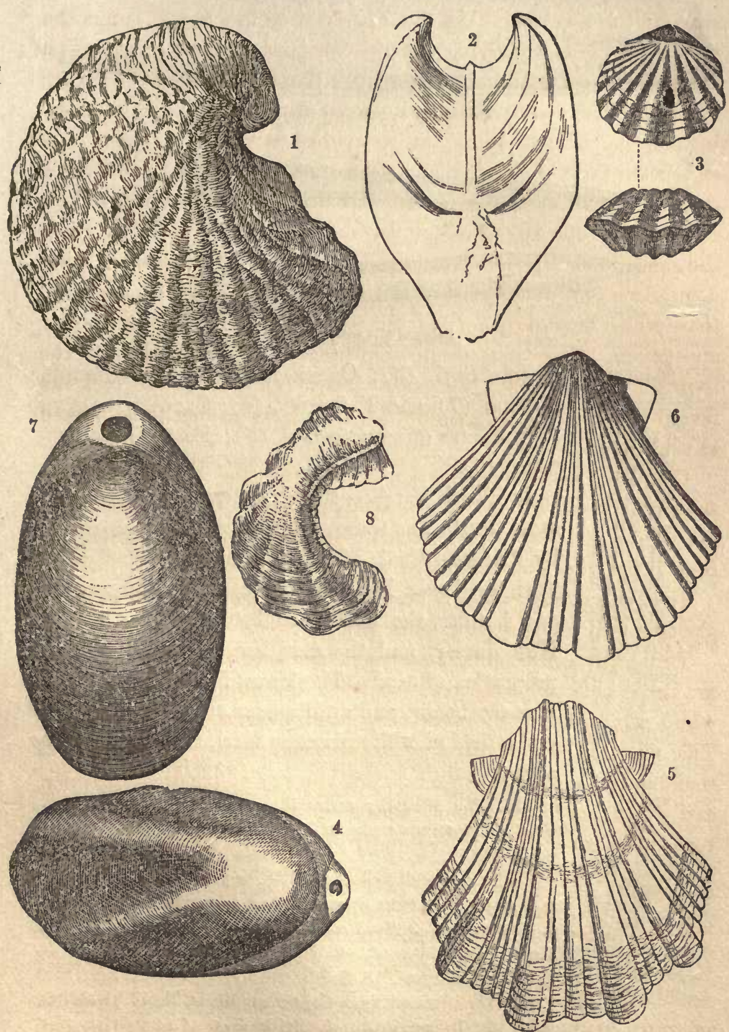
176. This system derives its name from the well-known substance, *white chalk*, used so extensively in marking. It is subdivided into *Lower* and *Upper* Cretaceous groups, which differ materially in their lithological characters.

The lower group is widely known as the Green-sand, and in many places simply as marl, as in New Jersey.

This group consists of six members, the most important of which are those beds of Green-sand (omitting the potter's clay beneath), which are separated by intervening beds of sand of various colors. The name of the Lower Cretaceous group is derived from small rounded particles of a green color, of the size of coarse gunpowder, and which consist mainly of silicate of iron. These are so numerous that a green color is frequently imparted to the bed. There is but a slight difference in the mineralogical characters of the three beds, though the upper contains fossils which do not occur in the lower. The lower or first bed of Green-sand supports a bed of reddish or yellowish sand quite ferruginous; and so the second supports a sand bed similar to that upon a sea beach. Although the presence of green grains will not in certain cases be sufficient to distinguish this part of the series from other rocks, as there are many localities where the green grains have been carried up into the Miocene beds. The fossils, however, are quite characteristic of the formation. The lower bed contains Exogyra costata, fig. 176 (1), Tere-

Fig. 176.

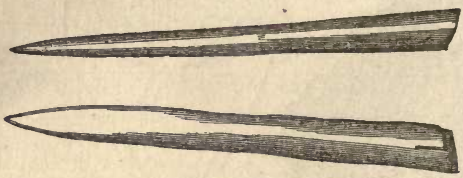
FOSSILS OF THE GREEN-SAND.



1. Exogyra costata. 2. Cuculea vulgaris (cast). 3. Terebratula Sayi. 4. Terebratula fragilis. 5 Janira quinquecostata (Neocomian). 6. Pecten quadricostata. 7. Terebratula Harlani. 8. Ostrea falcata.

Fig. 177.

Belemnitella Americana (Morton).



Belemnitella compressa, E.

Fig. 178.

bratula Sayi, (3); Ostrea falcata, (8); Terebratula Harlani, (7), and T. fragilis, (4); Cucullea vulgaris, (2); Janira quinquecostata, (5); Pecten quadricostatus, (6).

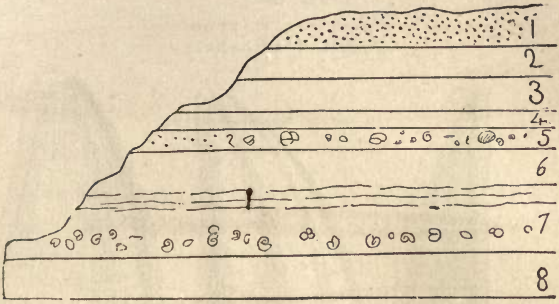
In North Carolina the Green-sand admits of the same division as those which have been pointed out by Professor Cook, of New Jersey, but it is believed that the lower bed does not come to the surface; and besides, the fossils are less numerous than in New Jersey, and the marl itself contains a larger proportion of sand. The lowest bed upon Cape Fear is sandy below, and argillaceous above, and supports a thin bed of white Miocene marl, the Eocene being absent.

177. The following series illustrates the relations of the Lower Cretaceous rocks in New Jersey and North Carolina. (Fig. 178.)

1. Fire clay of Woodbridge, N. J., or pure potter's, with sands and clays of various colors, resting upon the Triassic series. 2. Green-sand. 3. Sand-colored brown, yellow, &c. 4. Green-sand. 5. White-sand. 6. Upper Green-sand. 7. Sand and shell marl miocene. 8. Sand.

Fig. 179. Section upon Cape Fear River, N. C. 1. Marine sand. 2. Brown earth. 3. Brick clay. 4. Sand. 5. Shell marl. 6, 7, 8. Green-sand. The upper bed is argillaceous, and supports a thin bed of Miocene marl. The Eocene is absent in numerous places.

Fig. 179.



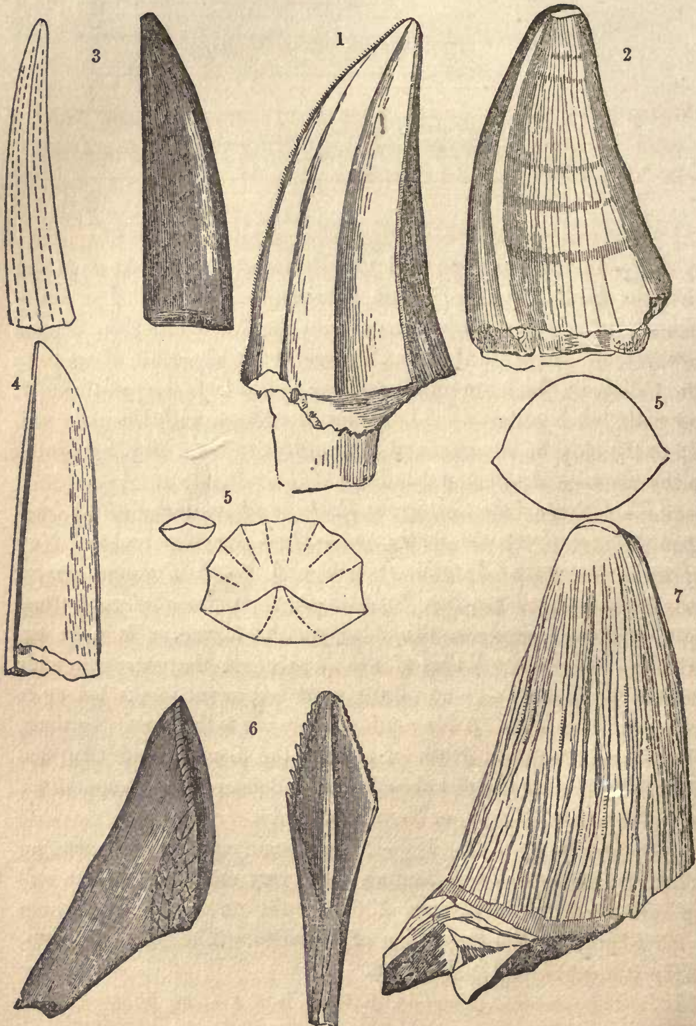
178. In Alabama we find the Cretaceous represented at the Prairie Bluff limestone, which consists, 1st, mainly of a white limestone, containing the Exogyra costata, Voluta Sayana, Pecten 5 costatus. Beneath this, or 2d place, is a white sand, about forty feet thick, in which are numbers of the Ostrea larva, Gryphea vomer, and Pecten 5 costatus. 3d, Rotten limestone, with Cucuella vulgaris; and, 4th, Concrete and loose sand, sand and clay, containing drift-wood, as at Choctaw Bluff, &c.

179. *Extent of the Cretaceous Rocks, and summary of the leading facts relative to the formation.*—The Cretaceous rocks of New Jersey, Delaware, Virginia, North and South Carolina appear in rather isolated patches, but still they are probably continuous and connected deposits. In Alabama the formation is more extended, and in the Valley of the Mississippi they occupy a wide extent of country. Some of the most important fossils belong to the vertebrate class. A Mammifer, belonging to the seals; Saurians, as the Mosasaurus; teeth of sharks, the Lamnas and Charcharias, Cephalopods in great abundance, as Belemnitellas, Ammonites, Baculites, Brachiopods, or Terebratulas, &c.

The Mosasaurus, fig. 180—2, was once regarded as belonging to a distinct genus, but Saurian teeth vary much in form as well as size. The Hadrosaurus, 180—6, was an enormous Saurian closely allied to the Iguanodon of Wealden. The genus Polyptochodon is also found in England.

Fig. 180.

FOSSIL SAURIANS.



1, 2. Teeth of the Mosasaurus. 3. Polygonodon rectus (Leidy). 4. Pristis of the Eocene. 5, 5. Sections of the Mosasaurus. 6. Hadrosaurus Foulkii (Leidy). 7. Polyptychodon rugosus, E.

CHAPTER XIX.

CAINOZOIC DIVISION—GENERAL CHARACTERISTICS OF THIS DIVISION—SIR CHARLES LYELL'S SUBDIVISIONS OF THE TERTIARY—EOCENE, MIOCENE, AND PLIOCENE, ETC.

180. WHEN the length of the three great divisions is computed by the amount of the accumulated sediments, the fact that these divisions are of very unequal length, is quite striking. The sediments of the Palæozoic divisions are enormously thick. When, however, we compare them with respect to their organic contents, the Palæozoic fossils are insignificant, or occupy comparatively a low rank, when placed by the side of the Cainozoic representatives. Up to the close of the Cretaceous, no imposing structure belonging to the mammal class had appeared, but immediately after, or at the beginning of the Cainozoic time, herds of large mammals appear upon the stage. There are Pachyderms, herbivorous quadrupeds, whose remains have been disinterred from the plaster of Montmartre, near Paris. Mammals, then, at once assume an importance. The reptiles, though numerous, have lost their standing as masters of existence; and from this epoch, onward to the present, the mammals increase in power and rank, until, finally, man appears upon the scene, the lord of this lower creation.

The aspect which the Tertiary epoch presents, distinguishes it, clearly, from all that had preceded it. It is not imagination, it is not theory, that these views are based upon; but observation, carried on in all parts of the earth. It is a deduction from facts, which point only in one direction, and which lead to the conclusions which we have stated.

Sir Charles Lyell's division of the Tertiary still commends itself to the student for its simplicity.

181. This general threefold division into *Eocene*, *Miocene*, and *Pliocene*, requires attention. In the first place, the divisions are determined by the numerical ratios which the extinct species in any given bed bear to the living. The Eocene expresses the dawn of

the present; hence, the ratio of the extinct species to the living ones is very large, or rather, the living species in the Eocene are very small, if compared with extinct ones. About *four* or *five* per cent. only of the fossils of the Eocene live upon the earth or in the sea at the present.

In the older Miocene, *seventeen* to *forty* per cent. of the species are living now. While in the Pliocene, or full dawn, the living species vary from *forty to ninety-five*. Hence, the relative age of the Tertiary beds is determined by a comparison of their enclosed fossils, with those which live at the present time.

These divisions admit of subdivisions, as Lower, Middle, and Upper, by which closer comparisons become practicable. It may appear, to the student, that the classification of the Tertiary is too artificial and arbitrary, and is wanting in philosophical principles. This is far from being the case. Under its artificial dress, it covers principles of the highest importance.

182. It is found that the most recent beds contain the remains of animals and plants, *all* of which are species whose identity with the living is fully established. If we go back one stage, the identity of only ninety-five per cent. is established; and if we go back still another stage, the ratio of the extinct to the living is still greater.

It is a consequence, then, perhaps too plain to require a statement, that the relative age of a bed is fixed when the ratio of the extinct to the living is determined; the nearer it is to the present, so much greater will be the ratio of its remains to those of our own times, and the less the ratio, the further removed it will be. Following out this idea, we soon reach a stage in our recession, when the present is unrepresented by living species. The resemblance becomes generic, on receding still farther in time, or, on reaching the Palæozoic period, the generic resemblance becomes too faint to be confidently asserted. The great and leading divisions of the Kingdoms of Nature, however, are still fixed, and strong, and as clearly distinguishable as at the present time. There are no monsters—no unclassifiable beings, who refuse to submit to the systematic arrangement of the zoologist and botanist; all is consistent, and in harmony with the present, though the genera and species of the present have disappeared in our retrospect of the past.

183. The Tertiary consists of marine and freshwater deposits, which are frequently confined to separate basins; and though they are sometimes spread over wide areas, yet they possess more of a

local character than the older formations. The chronology, in each case, is determined by the considerations and principles just stated. Our Atlantic coast furnishes an example, over which the Tertiaries are widely spread, and probably the Valley of the Mississippi and eastern slope of the Rocky Mountains are equally remarkable for the breadth and length of these more modern formations. On the contrary, the London and Paris basins are comparatively circumscribed, and yet have given law to our modes of investigation.

184. As a whole, the fossils of the Cainozoic division bear a stronger resemblance to those which now live than those belonging to the preceding periods.

The lithological characters of the basins, and estuaries, &c., must, of course, present great differences, and hence are not depended upon to determine their ages. They repose upon rocks of all periods, from the oldest to those which immediately precede their own. A difficulty is met with in the investigation of the Tertiary, especially in settling its chronology, which should be noticed in this place. It arises from the limited distribution of species, or their confinement to particular seas, estuaries, &c. Thus, the fauna of the Red Sea differs materially from that of the Mediterranean; so the influence of a particular sediment greatly influences the character of the animals which inhabit the area over which it prevails. Certain species live upon a muddy bottom; others, upon a sandy one; and the formation of these bottoms may have been simultaneous, and yet their faunas differ. But this kind of influence is not confined to the Tertiary deposits.

But we remark again, leaving out of the view the difficulties set forth in the foregoing paragraphs, it has been found, by actual experience, that the divergences of a fauna from the present ones, of any country we may select, has so many advantages in settling the chronology of a particular basin or a series of beds, that it cannot at present be dispensed with.

185. *The Eocene Formation of the Atlantic Slope.*—Lithologically, it has no unity of character.

On James river, the Eocene resembles, mineralogically, the Greensand. In North Carolina, the Eocene consists of white, soft marls, sometimes tinged brown or drab. Beds of the same age are consolidated, and become white limestone, as upon the Neuse, twenty miles above Newbern. They rest on soft marls, and the upper layers are frequently soft, also. These consolidated beds are often

silicious, and filled with rounded grains of sand. They rarely contain over seventy-five per cent. of lime. Higher up, on the Neuse, in Wayne county, these consolidated beds are associated with a light, laminated material, which would be suspected to consist of infusorial matter. It is, however, merely fine silex, with a very small proportion of calcareous matter.

Similar beds of Eocene exist at Wilmington, charged with the same kind of fossils as those at and near Newbern.

Between the Grove and Vance's Ferry, on the Santee river, S. C., there is a continuous, white soft limestone, extending forty miles, which belongs to this formation.

Upon the Savannah river, forty miles below Augusta, the white, indurated marl, together with the soft marls, are overlaid with red clays and loam. The formation seems to be completed by a deposition of silicious beds, which have been called the *Georgia buhrstone.* Like the Paris buhrstone, it has a rough appearance, and has many cavities. It passes into a sandstone with geodes, lined with crystals. Often, the interior of these geodes are agatized, and, in fine, passes into cacholong. Fine specimens of opal are occasionally found.

The Eocene of Alabama is, perhaps, more perfectly developed than in North and South Carolina, particularly at St. Stephen's and Clairbourne. In the descending order we find the following beds. 1. The superficial materials of recent origin. 2. White Eocene limestone at St. Stephen's and Clairbourne, containing Plagiostoma dumosum, Pecten Poulsoni, Scutella Lyellii, and bones of the Zeuglodon. 3. Bluish, buff, and green-colored sands, containing Cardita planicostata, &c. 4. A kind of buhrstone; a silicious porous rock, probably a freshwater deposit. 5. Buff-colored sands, clay and limestone. This is the base of the Eocene, and reposes upon the Prairie Bluff limestone which is equivalent to the green-sand, as it contains Exogyra costata, &c. These sands have numerous fossils which differ from those found at St. Stephen's and the superior beds of Clairbourne. At Vicksburg, on the Mississippi, the Eocene beds correspond with the upper Eocene at Clairbourne and St. Stephen's.

Foreign Localities.—Paris basin and London clay. Isle of Wight. The first consists of Upper and Lower, or the millstone above, the gypseous beds below, which contain the Palæotheria, Anoplotheria, Didelphis, and many other quadrupeds. The London clay corresponds to the Calcaire grosier, of the Paris basin. Both are rich in univalve and bivalve mollusks.

186. *Extent and Summary of Facts.*—The Eocene exists in Texas, Alabama, Mississippi, Arkansas, Louisiana, Georgia, North and South Carolina, Virginia, Maryland, and Delaware. Some of

Fig. 181.

Tooth of an Eocene Whale.

the beds resemble the green sand, as those near Petersburg, Va. Farther south, they are white marls, with about seventy-five per cent. of carbonate of lime, and from six to twenty-five per cent. of sand. These beds are frequently limestones.

187. *Miocene.*—It consists of a series of strata, which are clays, sands, and shell marls, of white, green, and brown colors. The shell marl in the South, exists only in isolated beds or banks, similar to modern oyster banks. They are surrounded by sands, and the shell banks may extend a quarter of a mile, but frequently they occupy only a few feet in length. Where the banks are well formed the bottom is composed of a few pebbles—coprolites, with teeth of the larger kinds of sharks; and hence it appears, that the Miocene was preceded by oscillations of the surface. In confirmation of this view, some of the beds upon the Cape Fear contain green-sand and its fossils, as the Exogyra costata, Belemnitella Americana, casts of Cucullea, &c.

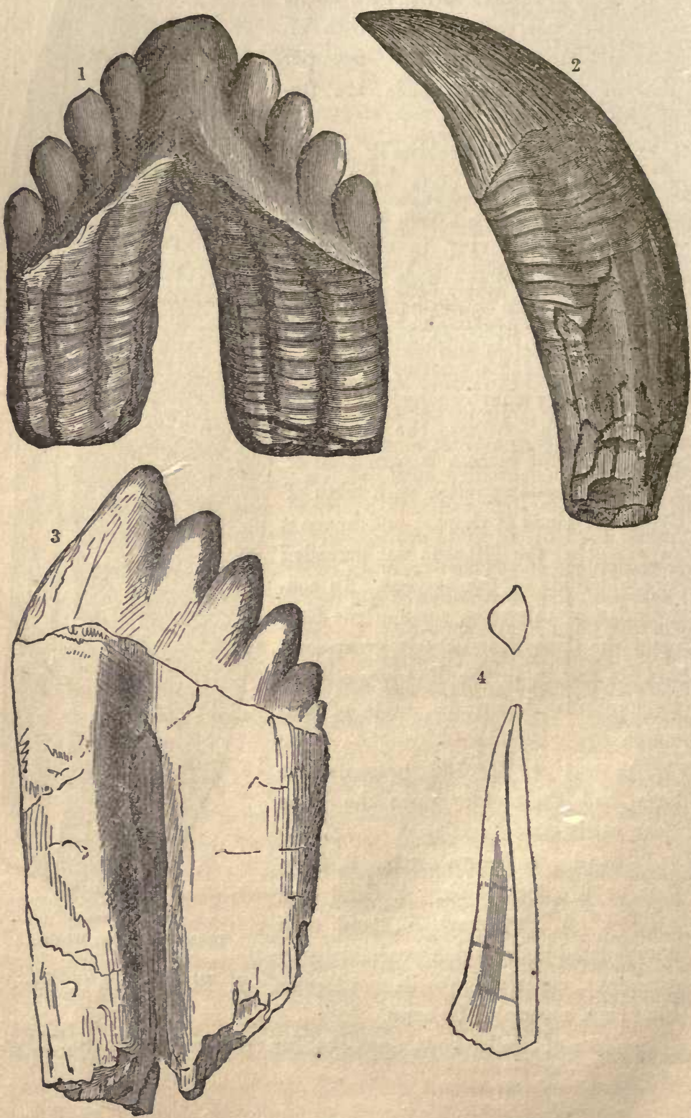
The section, fig. 184, presents the beds, and their order upon the Cape Fear, at Brown's Landing.

1. Sand. 2. Brown earth. 3. Clay, four or five feet thick. 4. Sand and pebbles. 5. Shell marl. 6. Sand, with consolidated beds, which resemble gray sandstone, containing fossils and lignite. 7. Blue clay. 8. Sand, blue clay, succeeded by sand.

Sections of similar beds, upon the Tar river, near Tarboro, Edgecombe co., N. C.

Fig. 182.

CETACEAN OF THE EOCENE.



1, 2, 3. Different teeth of the Zeuglodon, an Eocene Cetacean. 4. Enchodus ferox, a fish of the Green-sand.

Fig. 183.

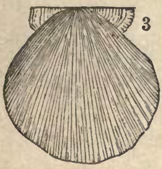
FOSSILS OF THE EOCENE.

1

2

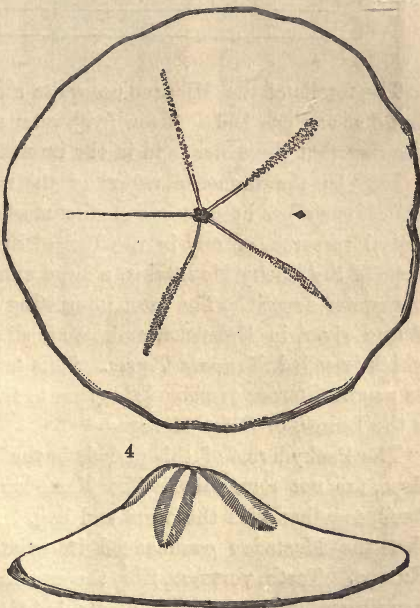
Nummulites ataica.

3



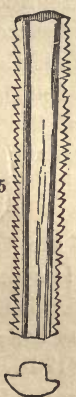
Pecten membranacea.

4



Scutella Newbernensis, E.

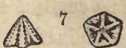
5



Trygon Carolinensis. E.

6

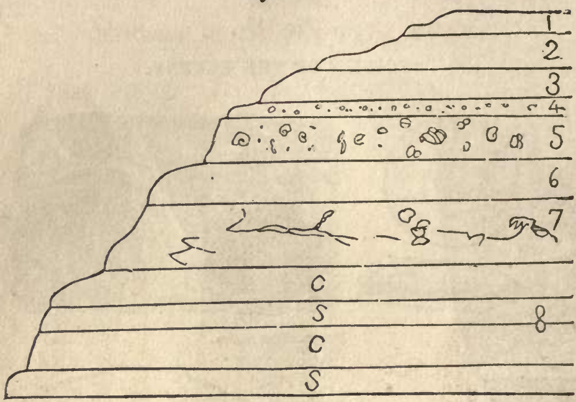
7



7. Microcrinus conoideus. E.
6. Echynocyamus parvus. E.

Echinus Ruffini.

Fig. 184.



The fossils of the Miocene are quite numerous; they are not all found at any one bed. A few freshwater shells are not uncommon, showing that there was land in the immediate vicinity.

188. In the immense region of the waters of the Mississippi, the Miocene has become one of the most interesting fields for geological research, of any in the United States. Upon the eastern slope of the Rocky Mountains, a large extent of this formation is a freshwater deposit. The most interesting part of this field, is upon White river, in Nebraska, embracing all that part of the region which is called *Mauvais Terres*. This formation is remarkable for its mammaliferous remains belonging to the order Pachyderms. It is the Lower, or Older Miocene.

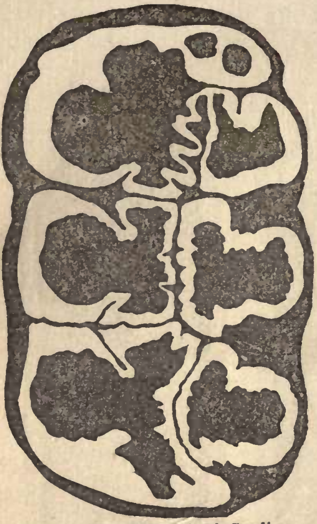
The Pachyderms of this period, in the Miocene of the Atlantic slope, are not numerous. The Mastodon, however, is a common fossil, together with the horse and hog. From this fact it follows, that the Mastodon commenced its existence here as early as in Europe. Teeth, vertebra, ribs, the cuneiform bone of the foot, &c., have been found at distant points. At the same time, it is true, the Mastodon is found in marls and peat bogs, resting upon the upper bed of the drift in New York. Of the same age, too, is that remarkable rodent, Castoroides Ohioensis. The earliest appearance of the Mastodon is in the Miocene. The generalization, therefore, which has been attempted relative to the age of this continent compared with Europe, is hasty, and is not well sustained.

Fig. 185.

MAMMALS OF THE OLDER MIOCENE.

1. Titanotherium proutii (Leidy). Left side of the Lower Jaw, showing the triturating surface. 2. Rhinoceros nebrascensis (Leidy). 3. Mylodon Harlani, an extinct Sloth. Big Bone Lick. Two-thirds the natural size.

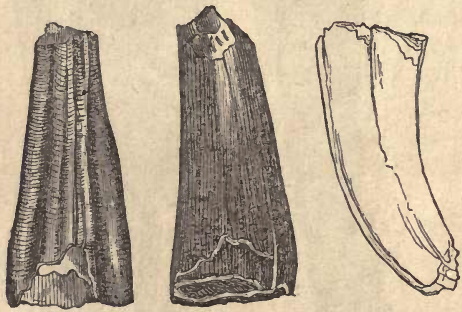
Fig. 186.



Mastodon, Marl Beds of North Carolina.

Grinder of the Hippopotamus.

Grinder of the extinct Horse.



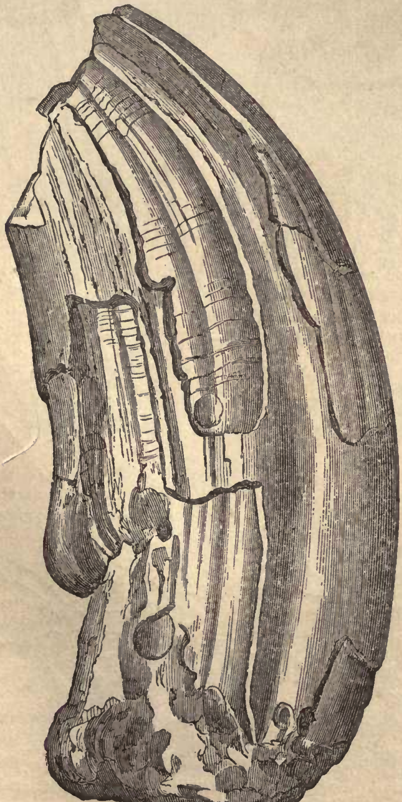
Incisors of the Horse, N. C.

Last Molar of the Under Jaw of the Pig, N. C.

Oreodon Culbertsoni (Leidy) *a.* Ruminant, Nebraska.

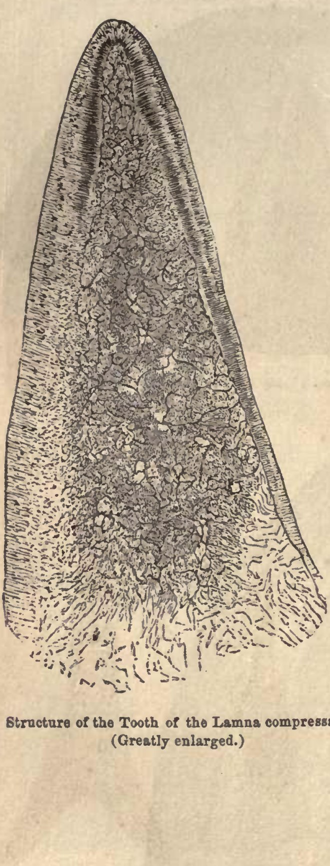
Fig. 187.

Testudo Oweni (Leidy).

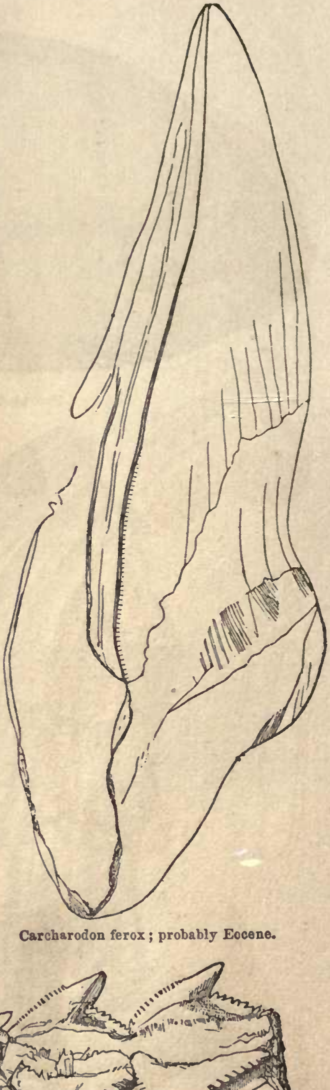


·etus Emmonsi (Leidy); Cetacean. (Half natural size.)

Fig. 188.



Structure of the Tooth of the Lamna compressa.
(Greatly enlarged.)

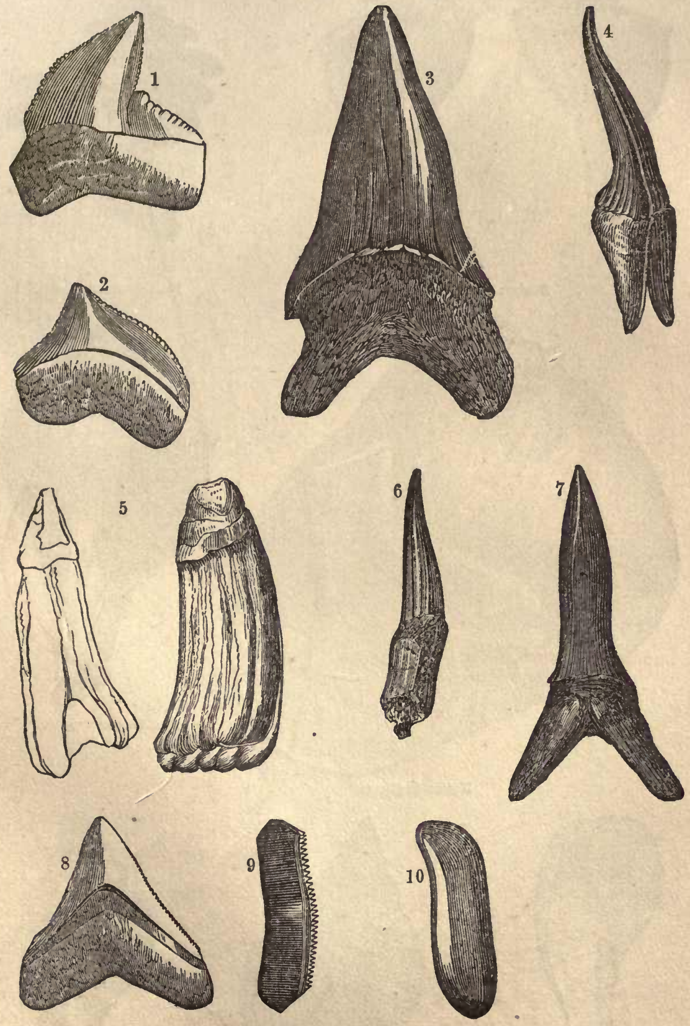


Carcharodon ferox; probably Eocene.

Arrangement of the Teeth of Sharks. (Galeocerdo arcticus.)

Fig. 189.

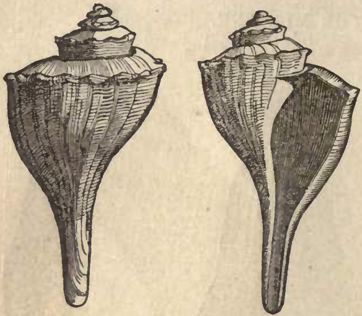
FISH OF THE MIOCENE.



1. Galeocerdo pristodontus. 2. Galeocerdo latidens. 3. Oxyrhina Desorii. 4, 6, 7. Lamna elegans. 5. Ischyriza antiqua. 8. Galeocerdo. 9. Trygon. 10. Pycnodont tooth.

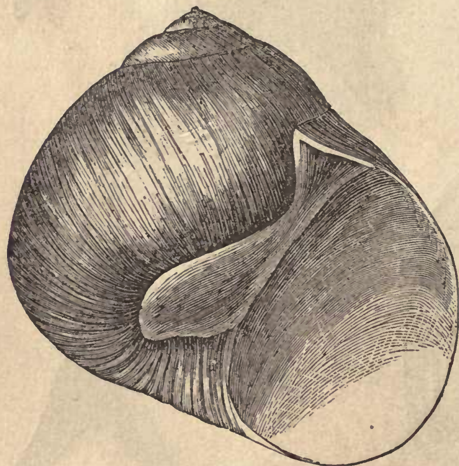
Fig. 190.

GASTEROPODA OF THE MIOCENE.

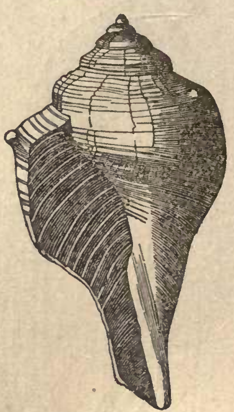


Busicon caniculatum.

Fusus quadricostatus



Natica duplicata.



Busicon perversum.

Pyrula reticulata.

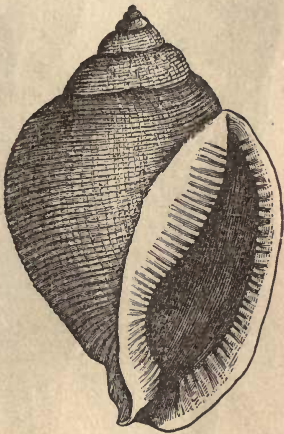
Cancellaria reticulata.

Fusus exilis.

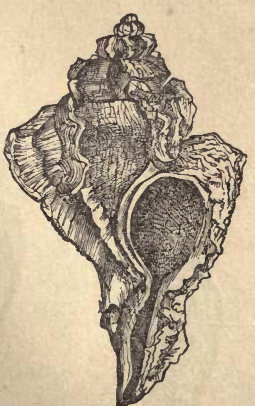
Fig. 191.

GASTEROPODS OF THE MIOCENE.

Murex globosa. (Half natural size.)



Galeodia Hodgii.



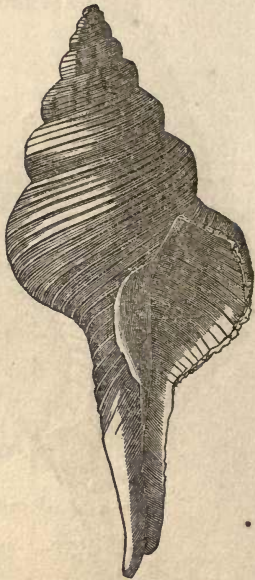
Murex umbrifer.

Fig. 192.

GASTEROPODS OF THE MIOCENE.

Terebra unilineata.

Voluta Trenholmii.



Fusus equalis, E.

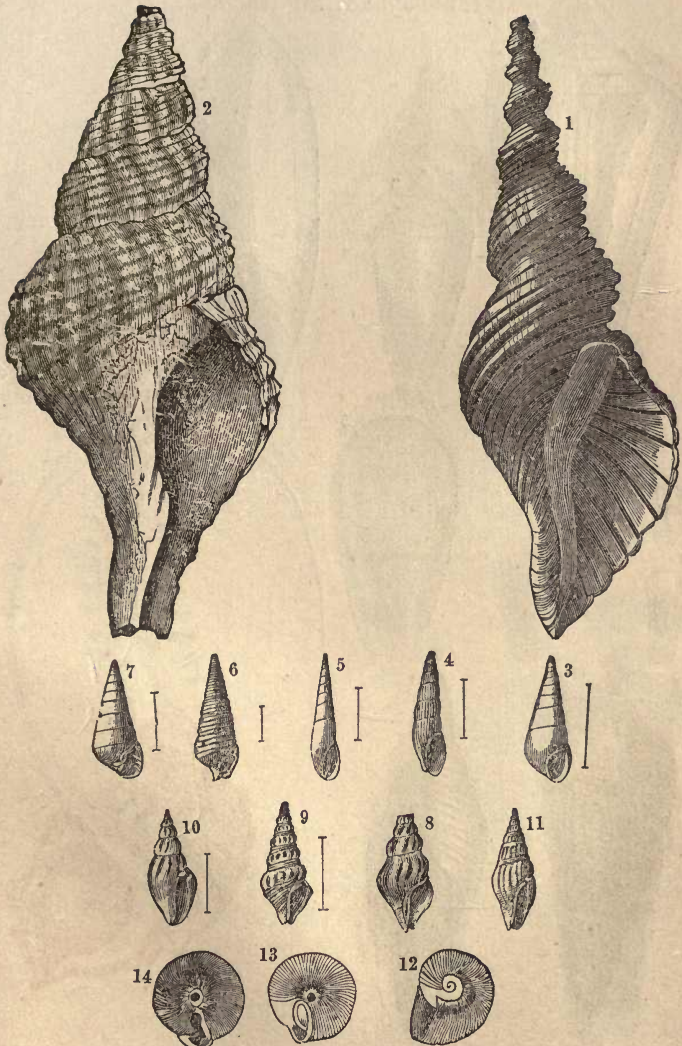
Pleurotoma lunatum.

Voluta obtusa.

Cancellaria Carolinensis.

Fig. 193.

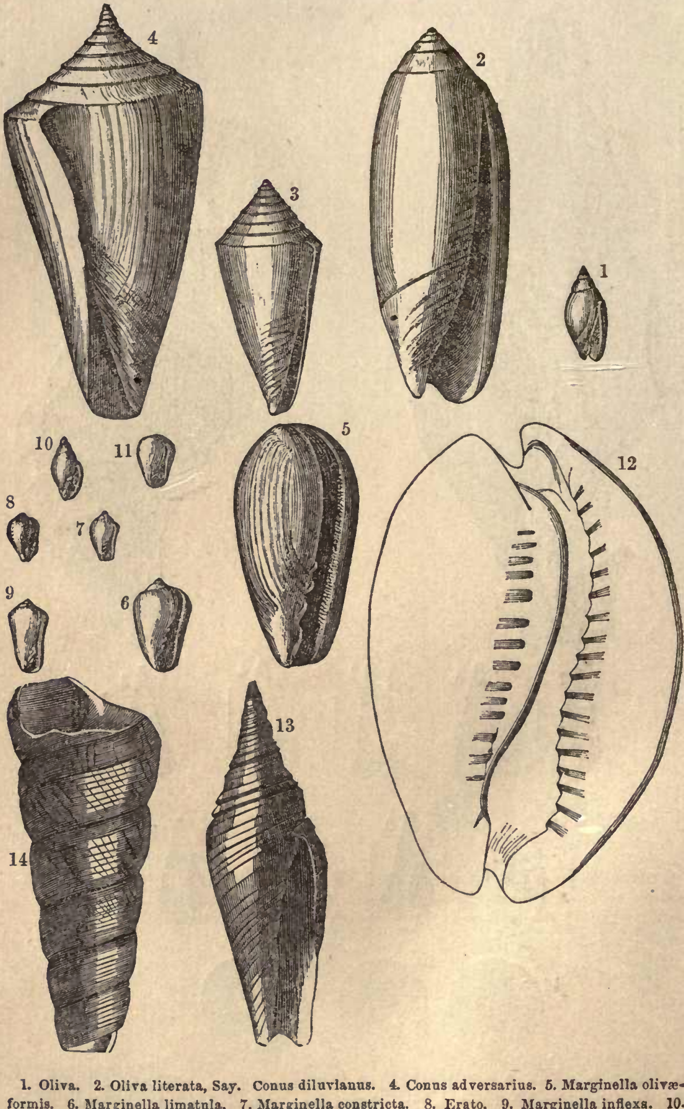
MIOCENE FOSSILS.



1. Fasciolaria elegans. 2. Fasciolaria Sparrovi. 3. Eulima lævigata. 4. Cerithium. 5. Eulima subulata. 6. Cerithium annulatum. 7. Pyramidella arenosa. 8. Pleurotoma flexuosa. 9. Pleurotoma tuberculata. 10. Pleurotoma limatula. 11. Pleurotoma elegans. 12. Planorbis bicarinata. 13. Helix labyrinthica. 14. Helix tridentata.

Fig. 194.

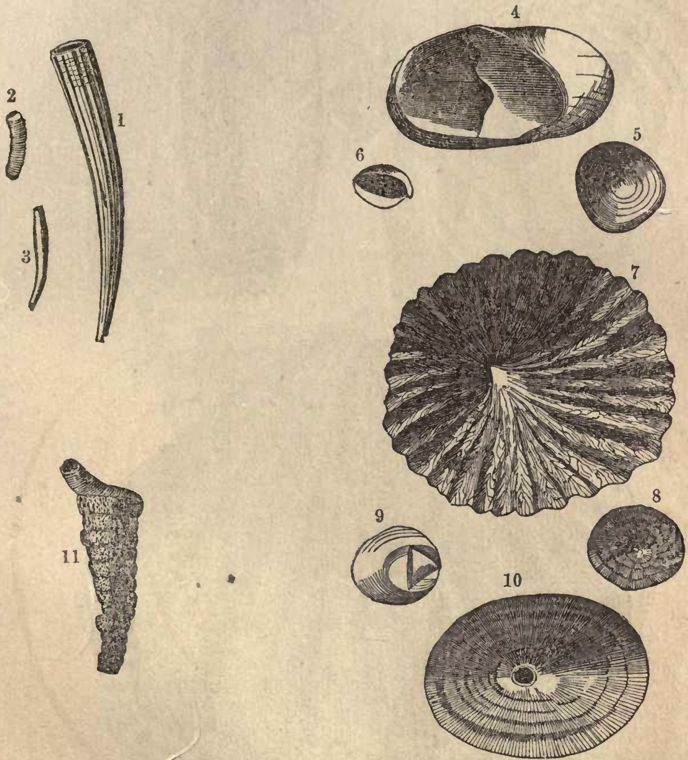
MIOCENE FOSSILS.



1. Oliva. 2. Oliva literata, Say. Conus diluvianus. 4. Conus adversarius. 5. Marginella olivæformis. 6. Marginella limatula. 7. Marginella constricta. 8. Erato. 9. Marginella inflexa. 10. Marginella elovata. 11. Marginella ovata. 12. Cyprea Carolinensis. 13. Mitra Carolinensis. 14. Terebellum constrictum.

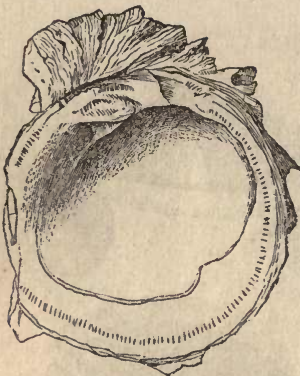
Fig. 195.

MIOCENE FOSSILS.

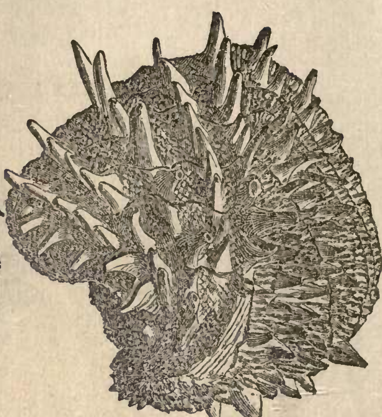


1. Dentalium attenuatum. 2. Cæcum annulatum. 3. Dentalium thallus. 4. Crepidula fornicatum. 5. Trochita centralis. 6. Crucibulum. 7. Crucibulum ramosum. 8. Crucibulum multilineatum. 9. Crepidula plana. 10. Fissurella redmicula. 11. Petaloconchus sculpturatus.

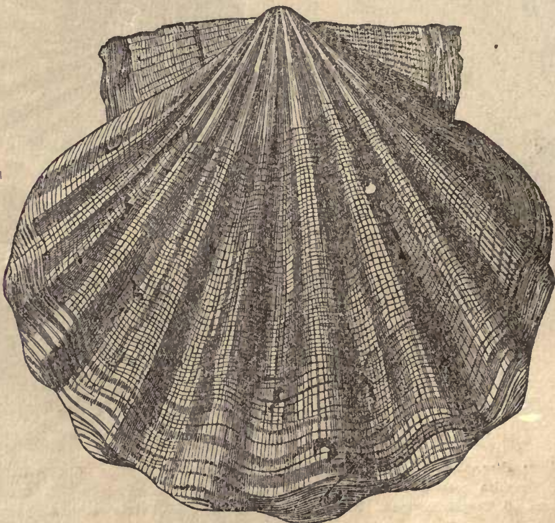
Fig. 196.
MIOCENE FOSSILS.



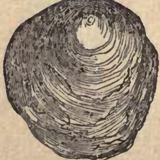
Chama corticosa.



Chama arcinella.



Pecten Jeffersonius.

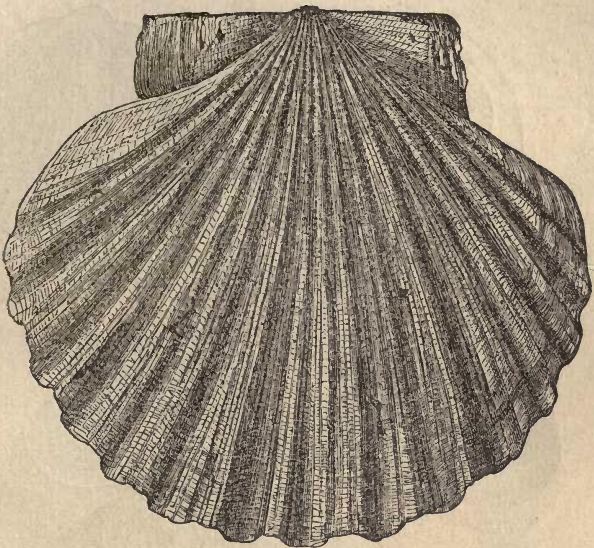


Orbicula lugubris.

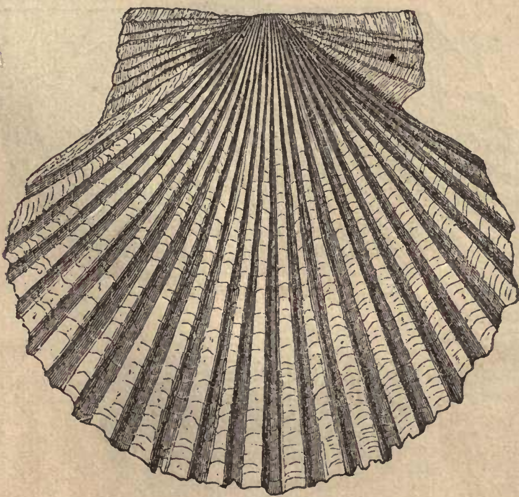
Plicatula marginata.

Fig. 197.

MIOCENE FOSSILS.



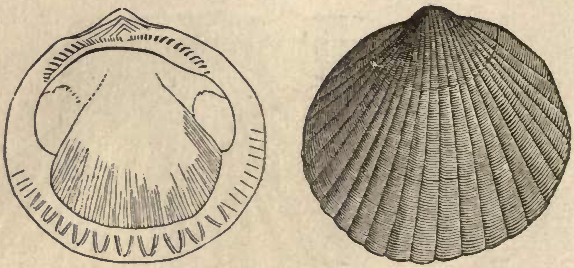
Pecten Madisonius.



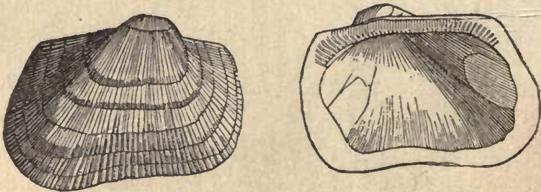
Pecten eboreus.

Fig. 198.

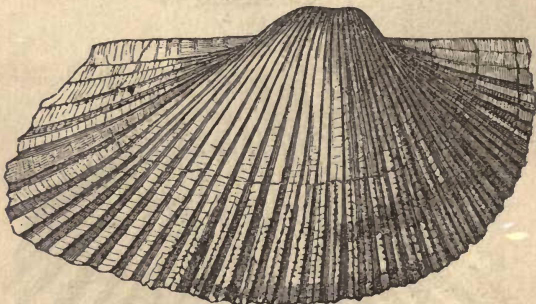
MIOCENE FOSSILS.



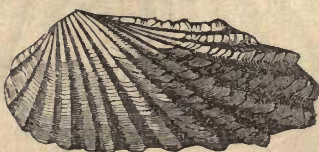
Axineæ subovatus.



Arca centenaria.



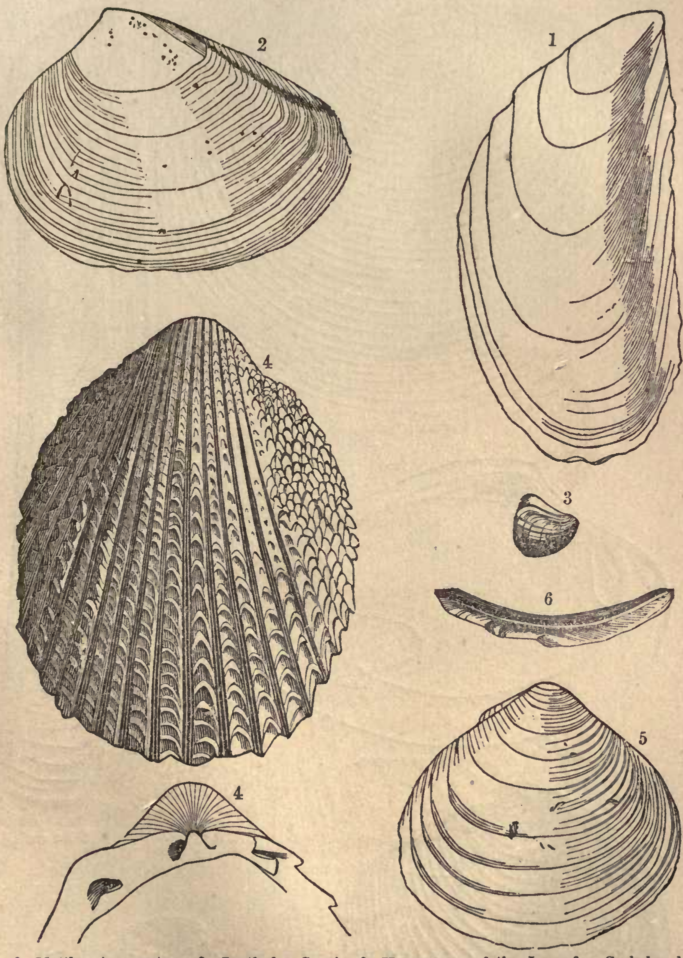
Arca lienosa.



Cardita arata.

Fig. 199.

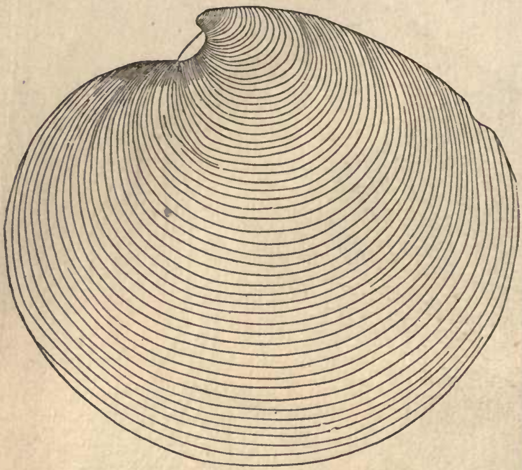
MIOCENE FOSSILS.



1. Mytilus incrassatus. 2. Gnathodon Grayi. 3. Horny core of the Jaw of a Cephalopod (Eocene). 4. Cardium muricatum? 5. Corbicula densata. 6. Valve of a Cirripoda.

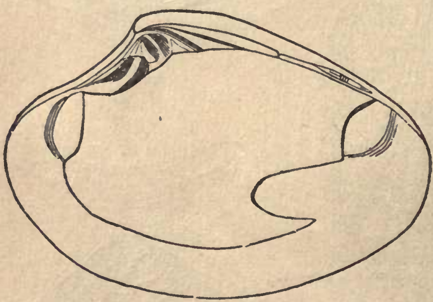
Fig. 200.

MIOCENE FOSSILS.

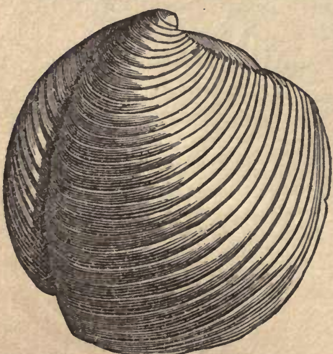


Dosinia elegans.

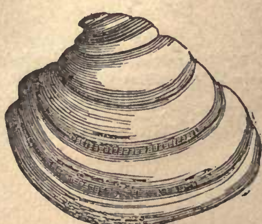
Solen ensis.



Cytherea reposta.

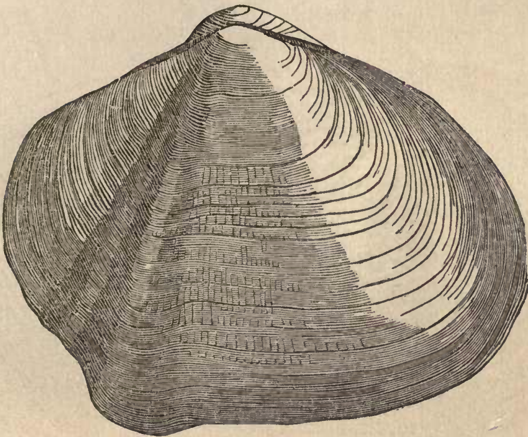


Lucina Pennsylvanica.

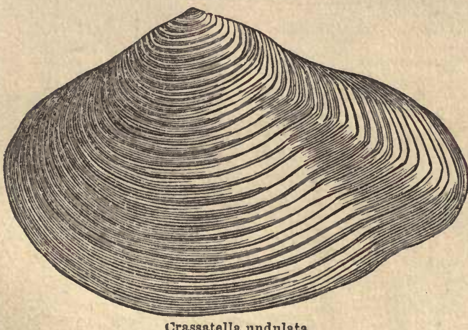


Venus latilirata.

Fig. 201.
MIOCENE FOSSILS.

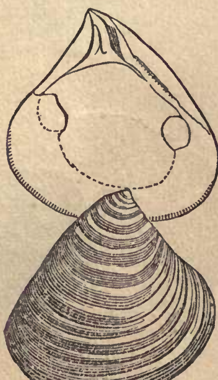


Tellina biplicata.



Crassatella undulata.

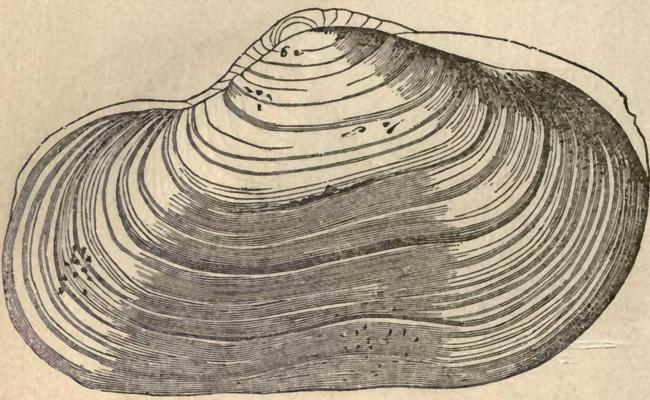
Venus cribraria.



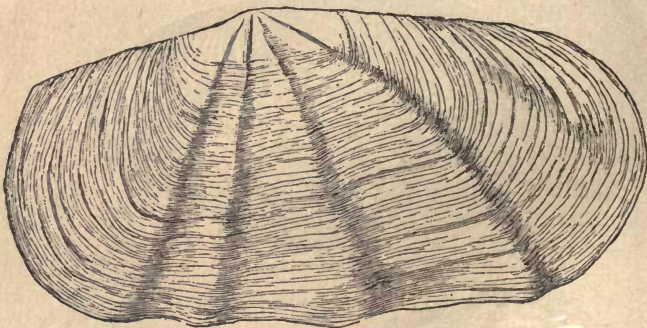
Astarte undulata.

Fig. 202.

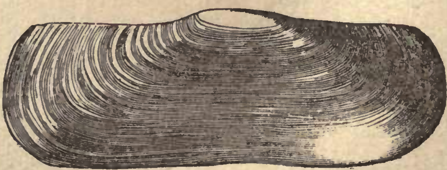
MIOCENE FOSSILS.



Glycimeris reflexa.



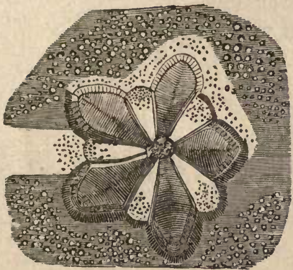
Glycimeris abrupta.



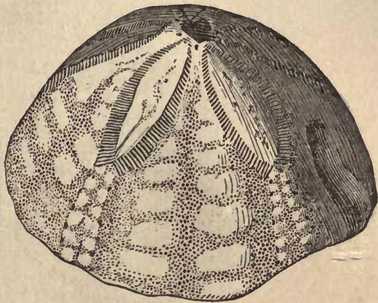
Solecurtis caribæus.

Fig. 203.

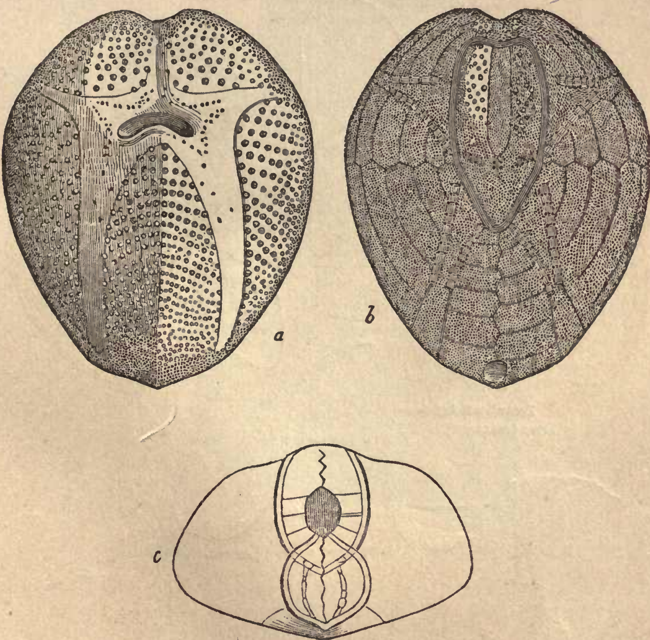
ECHINODERMATA OF THE MIOCENE.



Rosette, beneath.



Gonioclypeus subangulatus, E.

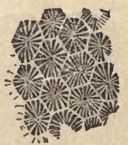


a, *b*, *c*. Amphidetus Virginianus (Forbes).

Fig. 204.

CORALS AND BRYOZOA OF THE MIOCENE.

Lunulites contigua.



Astrea bella.

Lunulites denticulatus (enlarged).

Astrea.

Fig. 205.

Tetralophodon, or Mastodon of the Miocene. (Half natural size.)

The elephant bones, which occur in New York, prove that it was cotemporaneous with the Mastodon there; but the elephant's remains have not been found in the Miocene marl.

The older Miocene of White River has furnished remarkable animal remains which have been described and finely illustrated by Prof. Leidy. Among these remains ruminants are particularly worthy of note. Several genera belong to those which were described by Cuvier, but which belonged to the Eocene, viz., the Anoplotherium and the Palæotherium giganteum; the latter being twice the size of the Palæotherium magnum of the Paris basin. Two species of Rhinoceros and several species of Tortoises, closely allied to the genus Emys, are not uncommon. The Cetacean, fig. 187 (2), is a remarkable form of tooth for this family—having a resemblance to the canine of the Hippopotamus.

189. *Pliocene.*—In this period the ocean had become divided into bays, estuaries, and gulfs, to about the same extent as they are at the present time. But oscillations of the surface to a much greater extent took place, and hence the frequent changes of level make it very difficult to recognise the formations of this period. Careful comparisons, however, of the species of mollusca which marine and fresh-water beds contain with those now living in the vicinity and upon the coast, will furnish the best data by which the age of any given bed may be determined. The group of fossils of the Pliocene, when compared with the living species, amount numerically to between 40 and 95 per cent., while the Miocene, as we have seen, only amount to between 20 and 40 per cent.

The Pliocene is older than the drift, and no doubt extensive beds belonging to this era have been entirely washed away, and probably in some, perhaps many instances, their organic contents have been lodged in boulder clays, or drift beds composed of sand, clay, and calcareous matter.

In Europe the Sicilian tertiaries, the crag of Norfolk, and subapennine marls, are referred to the Pliocene.

In this country they are always quite limited in extent, similar to isolated oyster banks; they differ considerably in mineral character, and in color; some are beds of sand, others are rich in lime, and form excellent fertilizers. In South Carolina the localities at which Pliocene beds occur, are the mouth of Little River, near the North Carolina boundary, Timber Landing, on Little River, Waccamaw River, and in North Carolina Waccamaw Lake, though this

is doubtful. Darlington District also contains numerous localities. Goose Creek, also, on the plantation of G. H. Smith, Esq.*

In North Carolina the Pliocene beds have not been sufficiently examined. Beds, which seem to lie in the horizon of those which are regarded as Pliocene in South Carolina, are rather Miocene; that is, they contain a less percentage of living species than those of South Carolina.

190. *The Post-Pliocene.*—Those shelly beds which contain 95 per cent. of living species, are placed under this head. They do not differ materially from the preceding in their mineral characteristics.

The most celebrated localities upon the Atlantic coast are those of Ashley Ferry, Goose Creek, Stono, and John's Island, in South Carolina.

These beds are remarkable for the number of mammalian remains which they contain.

Among the fossils which have been determined are the following:—Horse; Hippotherium; Tapir; Beaver; Rabbit; Megatherium; Mylodon Harlani; Mastodon; Megalonyx; Glyptodon; Cervus Virginiana; Opossum; Peccary, Hog; Bison, and Elk. Of these some are living at a distance, but not on the Atlantic coast, as the Tapir, Beaver, Bison, Elk, &c.

The following are extinct:—Mastodon, Megatherium, Megalonyx, Glyptodon, Mylodon, Equus, and two species of Hipparion.

These fossils are found in other states, and have been obtained from widely-separated localities. Whether the Ox, Elk, Bison, Peccary, Hog, and Tapir were the cotemporaries of the Mastodon, Megatherium, Mylodon, and Glyptodon is not certainly determined, but is rendered highly probable by the manner in which their remains are associated together, and in a common bed.

It should be observed that the ratio of extinct to the living mammals is very large, and differs materially in this respect from that which has been determined with respect to the mollusks.

Many large mammals, now extinct, have been found in the Pliocene. The Mammoth, an extinct elephant, fig. 206. Fig. 207, Tooth of the elephant found in Western New York.

* Prof. Holmes of Charleston has very carefully investigated these beds, and has given many interesting communications to the scientific world concerning them.

The Megatherium, whose bones have been found in caves and recent formations in the South-Western States, fig. 208. Another remarkable mammal, the Castoroides Ohioensis, or extinct beaver of an enormous size. Fig. 209 is an outline of its skull found in the marsh at Montezuma, New York.

The Mastodon, fig. 210, is the most common of the large extinct quadrupeds, skeletons having been found in New York nearly perfect.

The Great Irish Elk, fig. 211, seems to have been a cotemporary, but its remains have not yet been found in this country. The Mastodon began its career in the Miocene period, as teeth of the Tetralophodon have been found associated with true Miocene fossils.

Ear Bone of a Whale (Miocene). (Half natural size.)

MAMMALS OF THE GLACIAL OR POST-GLACIAL PERIOD.

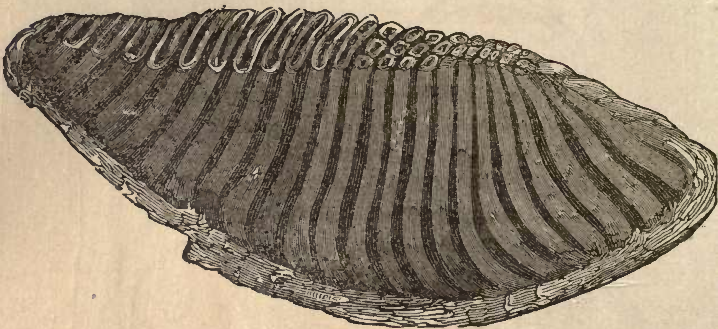
Fig. 206.

Mammoth or Extinct Elephant.

Referred, together with the succeeding plates, to Post-glacial, as their remains repose in beds upon the Drift.

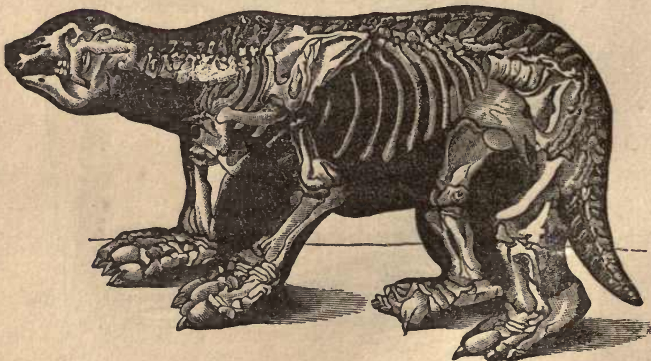
MAMMALS OF THE GLACIAL OR POST-GLACIAL PERIOD.

Fig. 207.



Tooth of the Fossil Elephant.

Fig. 208.

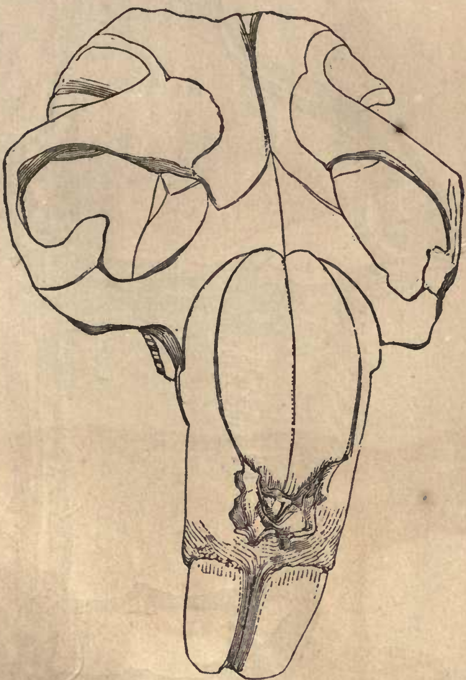


The Megatherium.

Elephant bones with the foregoing tooth were found in Cortland Co., N. Y.

Fig. 209.

MAMMALS OF THE POST-GLACIAL PERIOD.

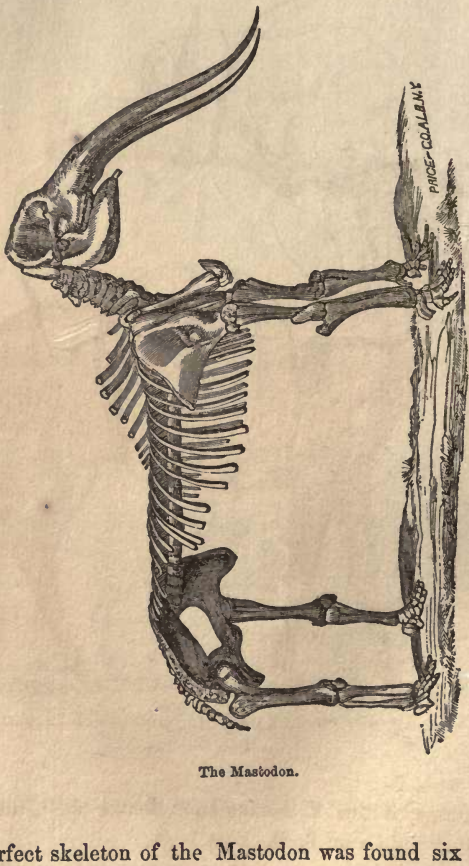


Casteroides Ohioensis. Extinct Beaver. One-third Natural Size.

The perfect cranium of this extinct Beaver was found in the Montezuma Marsh, New York.

Fig. 210.

MAMMALS OF THE POST-GLACIAL PERIOD.



The Mastodon.

The perfect skeleton of the Mastodon was found six miles west of Newberg, New York

Fig. 211.

The Great Irish Elk.

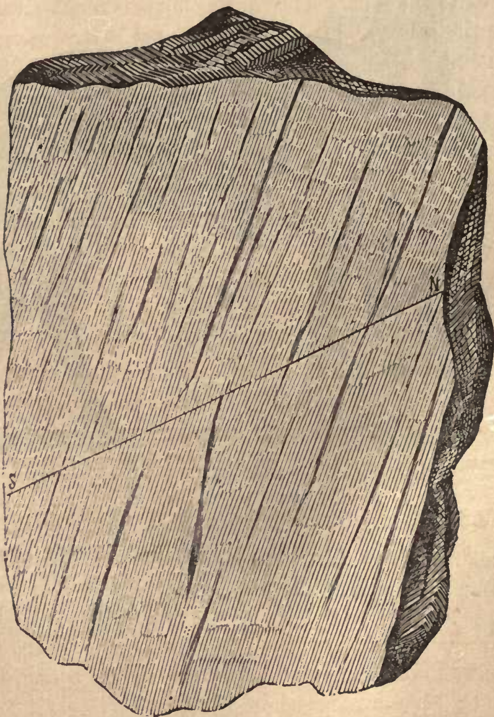
No remains of this Elk have been found in this country. In Europe they are found in the peat bogs.

CHAPTER XX.

GLACIAL OR DRIFT PERIOD.

191. THE phenomena which establish this period are based upon two separate and distinct classes of facts. The first, are impressed lines or grooves upon the rocks, which have a uniform direction over a large geographical area, and hence their explanation on the ground of accident becomes unphilosophical. The second fact is the existence of rounded and semi-rounded rocks far from their parent beds, fig. 212, but on certain lines of traverse, which, if fol-

Fig. 212.



Boulder Scratches.

lowed back along the direction of the impressed lines observed upon rocks, would lead to their original beds. Hence it follows that a force has moved these rocks in a certain direction, and the first fact stated the impressed lines, and the second fact the rocks distant from the beds, to which they must once have been attached, are linked together, and as phenomena are due to one cause. The moving rock scored or impressed the rock over which it passed. Several other facts should be stated: 1. The line of movement was northerly and southerly, north-east and south-west, or from the north-west to the south-east, with intermediate lines or directions. The reverse directions are unknown in the northern hemisphere. But in certain limited spaces, east and west, impressed lines exist, as we stated years ago, in the Cattskill Mountains.

We recognise, in these phenomena, a movement and a transportation of materials which we may now say was not confined to rocks, but extended to the soils. This movement was much more powerful towards the north, and its extent seems not to have passed south beyond the 40th degree of latitude, or the latitude of Baltimore.

192. The drift phenomena, when considered as a period, are subdivided into three subordinate ones: 1. A period of submergence; 2. A period of rest; and, 3. Of emergence. The division may appear objectionable, as it may seem to assume what is not proved; and it is probable it would follow as an inference from facts when stated, rather than to precede the facts from which the inference legitimately followed. The division, however, is borne out by facts which may be observed in Northern New York and Canada. They stand connected with three distinct beds of deposits; the first consisting of rounded rocks, usually called boulders, which lie in beds upon the naked rock, and in immediate contact with the scratched surface which has been described. The transportation of this bed of rocks, sand, &c., we connect with the period of submergence.

Upon these beds the clays of Champlain and Albany repose. This bed of clay, which is about one hundred feet thick, is a marine deposit, formed in quiet waters. The statement is sustained by the evenness of the strata, and the existence therein of marine, or estuary fossils. The deposition, then, of this great bed of clay, which is sandy towards the top, marks the second period, that of rest.

Upon this marine clay boulders are again found distributed in

beds, though generally isolated. They appear like the drift boulders, at the bottom of the clay. These mark the existence of the third period, the boulders being connected with the upward movements of the land, by which the marine deposit described was elevated, and reclaimed from the waters of this comparatively ancient sea. In the second period, during which the bed of clay and sand was being formed, boulders were occasionally transported from some distant point, and deposited in this clay, but the principal accumulations were at the beginning and close of the epoch.

193. The sequence of events appears to be well determined—first, the confused formation made up of travelled rocks, which could not have been thus transported without a movement of the land, which, from what followed, proves to have been a submergence; for we find, in the next place, the marine deposit, which must have accumulated under a considerable depth of water. In the third place, the land is lifted to its present level by an upward movement, which was effected probably by a rapid movement, which caused a speedy drainage by currents and streams, to which was imparted a competent force to move the loose rocks of the surface. The tendency would be to flow in the direction of the valleys; and hence, as the valleys are nearly north and south in New York and Vermont, the loose rocks would be carried in those channels.

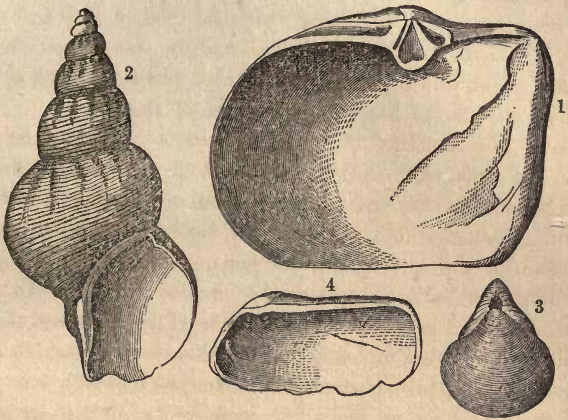
We pointed out, long ago, one of the consequences of this submergence, viz., the connection by water of the Gulf of St. Lawrence and the Bay of New York. This is sustained by the existence of the remains of whales in the clay, in the valley of Lake Champlain. An arm of the northern sea, extending to the Bay of New York, would admit of northern currents, and perhaps lie in the direction of the route which icebergs would travel. New England, and a part of New York, during the drift period, were an island, separated from the central part of New York by a narrow strait.

Other events appear to be connected with the drift period; the excavation of the soft rocks in the form of basins, which are now filled with fresh water. The long axes of the inland lakes of New York are directed not only in lines nearly parallel with each other, but also in the direction of the impressed lines upon the rocks. Lakes are no doubt due to diluvial action, as it is often called. Lakes proper scarcely exist in Southern States beyond the limits of the drift.

The lakes of North Carolina originated in fires which have con-

sumed the peat to a considerable depth. They are surrounded, and indeed based upon marine sands and clays, and are entirely removed from those causes which scooped out those lake basins in the Northern States.

Fig. 213.



1. Mya truncata. 2. Tritonium anglicum. 3. Rhynconella psittacea. 4. Saxicava rugosa.

The fossils of the Drift period are not numerous. In England the following list is given by Phillips:—Elephas primigenius, Hippopotamus major, Rhinoceros tichorhinus, Felis spelæa, Hyæna spelæa, all of which are extinct; besides which there are the bones of the wolf, horse, ox, and Irish elk. In New York the bones of the elephant are found in drift, and the bones of the Mastodon are found above the drift. The remains of the whale in the Valley of Lake Champlain belong also to this period. In the sands above the clay more than twenty species of mollusks have been obtained, most of which now live in latitudes farther north. The annexed are figures of some of the most common fossils of Lake Champlain and Beaufort, C. E., which belong to this period.

The foregoing division of the deposits which are closely connected with this period, may be admitted without adopting the theory that these changes of level were the efficient cause of the movements of boulders, gravel, soil, &c. The facts as stated relative to these changes of level must be admitted. The transportation of boulders by icebergs is another fact, the movement of glaciers is another, both of which are independent of the movements described.

This period is often called the Glacial period, because it was attended with a reduction of temperature, which seems to be supported by the occurrence of a fauna which strictly belongs to a

more northern region. It is probable, however, that the reduction was by no means excessive; and it also is probable the occurrence may be accounted for by the presence of icebergs, which might, during the submergence of the land already referred to, take the open channel between the Gulf of St. Lawrence and the Bay of New York. We now find occasionally boulders in the clay which appear to have been dropped from icebergs. They would not, however, be confined to this channel, but become stranded along the whole length of the then existing coast line.

194. The boulders, which belong to the Drift period, or Glacial epoch, are often confined to distinct belts of country. Some of these belts may be pointed out. They are distinguishable from other belts by the predominance of certain boulders which are peculiar, and whose parent rock is limited.

Thus the Adirondacks of Northern New York furnish all the Hypersthene rock which lies southward of this cluster of mountains. The most distinct belt, or train of boulders from these mountains, passes through Amsterdam, Montgomery county, New York. This village is upon the Erie Canal, thirty miles west of Albany. As this place is approached from the east, boulders of Hypersthene rock begin to appear. Near the village, and also a short distance to the west of it, they become abundant. Going farther west they diminish in numbers, and finally disappear entirely. The belt is about five miles wide. Going south, they will be found lying upon the northern slope of the Helderberg, over which they pass. Upon the slope, and in the valleys of the Catts-kill, they also occur. Some reach the extreme limits of Orange county. From Amsterdam northerly they may be traced to the Adirondacks, becoming more numerous near the parent beds; but to the north of them no boulders of this rock can be found. Another remarkable instance of a similar rock, which has travelled far, lies upon the eastern shore of Lake Ontario and the St. Lawrence. Hypersthene boulders, those referred to, though not very numerous, are sometimes met with. The feldspar of these boulders is of a lighter color, or has a bronze tint, instead of a blue, which is the most common tint of the labradorite of the Adirondacks. It might at first be maintained that they were also derived from the Adirondacks, but they cannot be traced in that direction. To the eastward they disappear entirely, and hence, in order to find the direction from which they came, it is necessary to follow the train.

This leads in the direction of Labrador, where this rock is known to exist.

The calciferous sand rock of Lake Champlain, the quartz rock at the base of the Taconic system, may each be followed more than a hundred miles in a north and south direction.

When a hard rock of a peculiar kind is scattered upon the surface, it may be traced to the source from which it was derived. The magnetic iron ores occur in the drift in Greenbush, and the neighborhood of Albany, which no doubt came from the western side of Lake Champlain.

195. From the foregoing facts, we find that boulders not only lie in valleys, but they have been carried up steep declivities, and over mountains, and from one valley to another. They must therefore have been transported by agents which are not now in operation. In the Northern States the lines or grooves, scored upon the rocks, point to the Arctic regions. There are no mountains which can be regarded as the culminating points to which boulders can be traced, and from which they have radiated in different directions, which would have been the case had they been carried forward by glaciers.

The Drift period, though remote, is undoubtedly the last which is connected with the great changes which have taken place upon the earth's surface. The materials moved rest upon all the general formations which have as yet been recognised. Beds of recent origin, the alluvials, &c., are more recent. A similar period of minor importance occurred in the period to which the Trenton limestone belongs. On splitting off a mass from a ledge of Trenton limestone, the mass split so as to be directly on a scored and grooved surface, the piece split off exhibited the relief side, and the fixed portion of the rock the scored surface. This mass may be examined at Plattsburg, immediately west of the village upon the river's bank. Four miles north, at Cumberland Head, the same stratum can be recognised, with its scored surface, as at the village. The striæ of the Trenton epoch run east and west. Probably similar phenomena may be observed by an attentive examination of the rocks belonging to other periods.

The contour of the country, during the epoch of the drift, was probably much the same as now. This opinion is based upon the deflection of the train of boulders when they approached a range of mountains. The current bearing along boulders towards the

Cattskill Mountains was deflected near the base to the eastward; the train, in part, instead of passing directly over the highest part, crossed the valley of the Hudson, and we find boulders of the Oriskany sandstone on the east side of the river, which were torn from the northern slope of the Helderberg. Some of the lower valleys of the Cattskill retain, east and west, lines of scoring as distinct as those at the base. These were, no doubt, due to deflection.

196. The force which carried boulders over surfaces so uneven, and up steep declivities, must have been immense. Upon the northwest side of Stonehill, in Williamstown, the rock of which is quartz, superficial indentations may be seen upon some of the cliffs, proving that the surface was struck with great force by moving rocks.

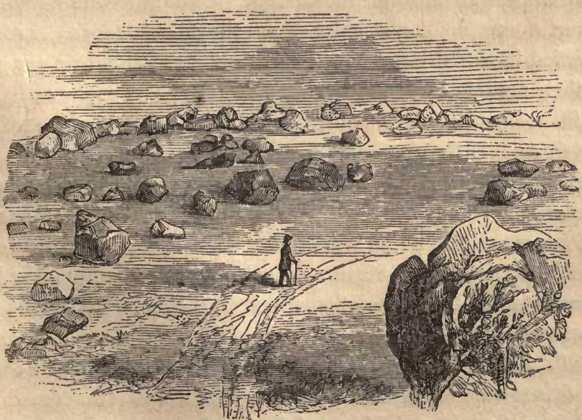
The Drift period was considerably protracted. We infer this from the changes which the surface underwent during its continuance. Rocks, for example, were deeply scooped out, and vast masses removed by denudation. In Williamstown about 1600 feet of Oakhill was worn down and removed, leaving still an elevation of 1700 feet. The whole of the slates and limestone, equivalent to those of Graylock, a few miles south, down to the quartz rock, were removed by denudation. Graylock is 3600 feet above the level of the sea, and the quartz rock, at its base, is about 700 feet. All above the quartz, then, of Oakhill has been removed, as this is its top rock.

We have then sufficient evidence that violence and great commotion belonged to the Drift era, and that it was not a transient one, but occupied a period of considerable duration, during which large portions of important formations were actually worn away, and transported to distant points. The hard rocks, those which were capable of resisting violent shocks, lie still along the path over which the formation travelled, telling us not only the fact of its removal, but also much relative to the force employed and the quantity of material acted upon. These materials are deposited in valleys, upon the slopes of mountains, and indeed they constitute the great part of New England and New York soils, wherever they may lie.

197. In conclusion, we remark, that it is no discredit to the geologist to acknowledge his inability to offer a satisfactory explanation of all the phenomena we have spoken of. We believe that the glacial theory of Agassiz explains fully a certain class of phe-

nomena, and that the iceberg theory of Sir Charles Lyell must be received in explanation of many other facts which stand in intimate relation to this subject. We believe, however, that the soil in a body has been moved, with its boulders intermixed, and hence, in order to account for a general movement of loose materials, we believe it necessary the land should rapidly subside, by which the barriers of a great northern sea would be removed. A rush of waters would follow sufficient to force along not only the loose matters, but break up the fixed rocks. The Erie Canal, in some of its worst breaks, has torn up the fixed beds of slate and limestone upon its borders. But the force of the waters of the Erie Canal, when unrestrained by its banks, is nothing in comparison to a deluge of oceanic waters unrestrained by shores.

We have spoken of the passage of boulders up the face of steep slopes, and the existence of striæ indicating such a movement upon the western face of the Taconic range in Petersburg, N. Y. These scratches or striæ may be explained on the ground that ancient glaciers once existed upon the peaks of this range; and what is confirmatory of this view is the existence also of ridges of sand and pebbles in some of the valleys which possess the character of moraines in a marked degree.



Boulders.

CHAPTER XXI.

POST-GLACIAL BEDS — ALLUVIUM — EOLIAN SANDS — BOTTOM PRAIRIE—BLUFF AND RIVER TERRACES—COAST SEDIMENTS—CAVERN DEPOSITS — TRAVERTIN — CORAL REEFS — VOLCANIC PRODUCTIONS.

198. POST-GLACIAL beds embrace a heterogeneous series of deposits, which are still more local than those which are classed under the Cainozoic division. They embrace the Quaternary deposits of many geologists. Under either name they include the *Alluvium*, *Eolian* sand, coast and deep sea sediments, cavern deposits, bog or peat, travertin, coral reefs, and volcanic productions, Bottom prairie and Bluff formation of the West.

The Glacial formation is excluded, on the ground that it is quite peculiar and distinct in itself, and occupies a definite though undetermined period, and moreover preceded the post-glacial beds. The latter, excepting the Bottom prairie and Bluff formation of Professor Swallow, are products of the present. Certain cavern deposits and travertin are no doubt older than the Glacial epoch, but those included in this division may be distinguished from the pre-glacial, by their organic contents, if they have any.

199. *Alluvium*, or washed strata, are accumulations of sand, gravel, and earth upon the banks, and at the mouths of rivers. They are quite limited, excepting upon such broad rivers as the Mississippi. They contain leaves and trunks of trees of our time, and bones of the living vertebrates, and mollusks of the stream which has deposited the bed. Alluvium may be distinguished from other deposits by the relation which it holds to the agent which deposits it.

200. *Eolian Sands.*—They are coast sands, which are continually driven inwards by the prevalent winds upon the coast. The sands are first brought forward by breakers, or strong waves, and carried up beyond the reach of subsequent waves, partly by the aid of wind. The Kill-Devil Hills, near Nag's Head, and all the sandbanks along the coast of North Carolina, are Eolian.

When the lighter implements of iron, as spears and fishing tools, coins, &c., are lost in the midst of the shore waves, they are cast ashore in a few days. The winds, however, drive the sand for miles inland, and frequently pile it in banks, intermixed with shells, which are also carried inland during strong gales.

201. *Bottom Prairie, Lagoon, and Lake Deposits.*—In the great valleys of the West there is an extensive formation, which has been called by Professor Swallow *Bottom Prairie.* It was formed by agencies which have ceased to operate. Perhaps it was deposited from lagoons when the course of those large western rivers was obstructed. Bottom prairies are composed of sand clays and vegetable mould, all of which are arranged in strata. They constitute the rich bottom lands of this region. The action of the present rivers is to wear away these bottoms, and form therefrom the alluvial bottoms.

202. *Bluff and River Terraces.*—This formation is geographically higher, and occupies ridges and river bluffs, but it descends, and sinks beneath the prairie bottoms. The material is silicious, stained with iron, and is also marly. Its stratification is irregular. It rests on the glacial accumulations.

In the West this formation is quite extensive. "It caps," according to Professor Swallow, "all the bluffs of the Missouri, from Council Bluffs to its mouth, and those of the Mississippi from the mouth of the Des Moines river to that of the Ohio." Other authors notice this formation as existing upon the Wabash, Ohio, and Red river.

The foregoing formation, *post-glacial,* frequently contains organic remains in great abundance. They do not differ from the living fauna except in the Vertebrates, and it is not easy to determine whetner in these instances they were not derived from older beds. The mollusks, both terrestrial and fluviatile, belong to existing genera and species; and yet there are, no doubt, many beds which have been deposited since the Glacial epoch, which are really very old.

This formation is regarded as lacustrian by Professor Swallow, who maintains that the sites of the great valleys of the Mississippi and Missouri contained large lakes, receiving rivers and smaller streams.

The river valleys of New York and New England have preserved terraces, which frequently assume the form of bluffs, which

probably date back to the period of the bluff formation of the Western river valleys. Their origin in New England may have been connected with an early condition of the river courses. Obstruction of their courses by barriers, causing expansions into lakes, which may have been connected with a change of level of the country, and the wearing down of obstructions, and may also, in the course of time, have formed the succession of terraces which skirt the valleys. The terraces are not perfect, and similar on both sides of the river, at the opposite points, but rather alternations of them from one to the other side.

In the Southern States old river bottoms are easily recognised by beds of gravel and rounded stones of a suitable size for pavements. These bottoms are fifty feet, sometimes more, above the present beds of the rivers. They exist even near their sources. We find beds of this description far in the interior of North Carolina, at Morganton, and Eastern Tennessee, and at many places west of the Alleghanies.

203. *Coast Sediments and Sediments of Deep Soundings.*—The materials which are brought to the ocean, or its bays and sounds, are continually receiving accessions of mud, sand, and gravel, land plants and terrestrial animals. So also the shore and the deep sea are continually receiving the sediments brought down by all the large rivers. This matter is in one sense sifted and assorted. The calcareous matter is carried out to sea, and is destined to build or raise the bottom of the deep sea, while the sand is deposited along the coast, or in shallow water.

204. *Cavern Deposits.*—In all caverns and caves water percolates through the roof, and carries along matters which it has dissolved. A part of this is retained, or adheres to the roof and wall, and if pendent, is called *stalactite;* that portion deposited upon the floor is *stalagmite.* The process goes on continually. Bones of bats, mice, and frequently the larger quadrupeds, are encased in stalagmite, or mud, which is brought in by streams.

The most ancient caverns date back to a period before the Glacial epoch, and contain bones of extinct quadrupeds.

205. *Travertin, or Tufa.*—Springs which issue from and flow over calcareous rocks, dissolve lime, provided the water holds in solution carbonic acid. When these waters reach the air, a part of the carbonic acid escapes, and lime is deposited in a bank. It is a porous mass, in which leaves, sticks, and logs are enveloped, and

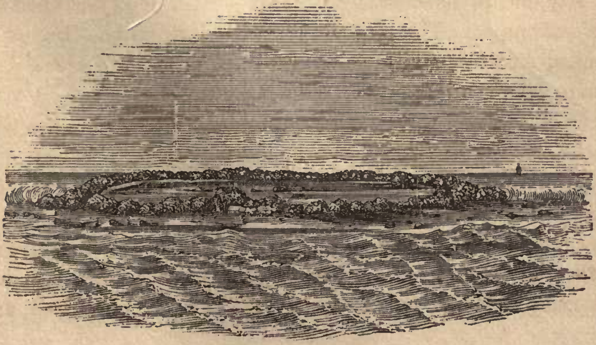
which are often petrified. Sometimes bog ores, mixed with manganese, are deposited, like travertin. Many such springs have dried up, or cease to flow; but the bog ore or ochre remains, adhering to stones, forming a ferruginous conglomerate.

206. *Coral Reefs, Shell Beds, &c.*—In warm latitudes polyps are busily engaged in building up their curious calcareous habitations. The coast of Australia, the islands of the Pacific, and the Bermudas furnish examples of coral reefs on a large scale. Coral reefs begin to be formed upon sunken islands, around sunken volcanic cones, and along coasts where the water is 30 or 40 fathoms deep. The coral rises to the surface, when it is broken by winds, and heaped up, and additions are made to the rising ridge from various quarters, as dead shells, till finally the ridges rise above high water, when they are resorted to by birds. Seeds germinate, trees and shrubs grow, and an island is seen to have risen from the depths of mid-ocean.

The coral reefs of Bermuda consist partly of a chalky mass made up of comminuted corals and shells. Where coral cliffs are found, or banks which rise considerably above the level of the sea, as in the West Indies; they are ascribed to volcanic action.

Where corals begin to build their habitation upon sunken peaks, they rise to the surface in a circular form, and enclose within a salt lake; such an arrangement of coral is called an *Atoll.* The process of building goes on while the land below is still slowly sinking, as is proved by the existence of dead coral, at a depth of 1500 or more feet, a depth which is incompatible with the existence of this class of animals.

207. *Volcanic Productions.*—Modern lava and ashes, mud, &c., thrown out within the historic era, belong to this order of deposits.



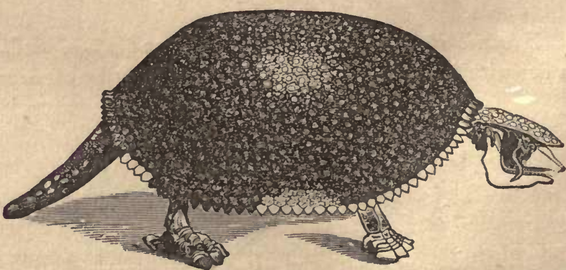
Atoll with its fringe of cocoanut trees and lagoon within.

EXTINCT MAMMALS OF THE SLOTH AND ARMADILLO TRIBES.

Fig. 214.

Mylodon robustus.

Fig. 215.



Glyptodon clavipes.

CHAPTER XXII.

VOLCANOES, VOLCANIC ACTION, AND EARTHQUAKES.

208. The principles which have been stated in the preceding chapters respecting the forces and agencies which are seated in the earth's crust, have prepared the way for what remains to be said relative to Volcanoes and Earthquakes.

Volcano is a word which is applied to a mountain or tract of country from which outbursts of fire, molten rocks, ashes, vapors, &c., take place from the interior of the earth. It usually occupies elevated points, and hence has arisen the term *Volcanic Mountains*. But they appear also in depressed areas, and even beneath the sea, when they are called submarine.

The form which the summits of a volcanic mountain assume are conical, or that of a cone, which arises from the accumulation of ejected matters from the vent, fig. 216. The cone itself is com-

Fig. 216.

Volcanic Cones.

posed of ashes and stones, which fall around the vent during its active stage. The molten rock, which also issues from the same vent, or from the mountain's side below, flows away like a river of fire, and when cooled remains a stream of black porous slag. Ejections, however, are not always molten and fiery; mud is sometimes ejected. Volcanoes are irregular in their action; there are periods of repose and of activity, and the intervals between them are of different lengths. The symptoms which precede an outburst are not numerous, but there are usually rumbling sounds beneath,

and frequently there is a perfect calm and quietude of the atmosphere. The outburst of a volcano is accompanied by the emission of flame, vapors, explosions, violent expulsion of ashes and stones, some of which are projected to great distances. The cloud of ashes is often sufficient to darken the atmosphere for fifty miles around, and even at times to cause the darkness of night. The force of volcanic action is immense. In one instance, in South America, a rock weighing 200 tons was projected nine miles. The force is still more strongly shown in the elevation of a column of lava several thousand feet through the funnel of the volcano, or in the elevation of large tracts of land. Thus in Mexico, three or four square miles in extent were raised 550 feet, from which height there were raised numerous conical hills, of 300 or 400 feet together, with the mountain *Jorullo*, 1600 feet high.

209. A volcanic mountain may be regarded somewhat in the light of an arch, which has been raised upwards by the expansion of vapors and gases, beneath which it is often excavated, furnishing room thereby for the accumulation of steam, vapor, or elastic gases; and as they are arranged in lines, and as they seem frequently to have open passages of communication, a volcanic range, as the Andes, for example, may be quite hollow beneath throughout their whole extent. The loss of subterranean substance, during a single operation, is frequently immense, as was the case in Iceland during the activity of Hecla, in 1783; when a molten stream of rock flowed down its sides for forty-two days, which travelled fifty miles, and then branched into two streams, one of which was forty and the other fifty miles in length. These streams varied in depth and width, according to the face of the country, ranging, however, from 600 to 1000 feet in depth. Its greatest breadth was fifteen miles.

A South American chain of volcanic vents runs east and west, beginning with the Tuxtula, on the Mexican Gulf; it runs west to the snowy peaks of Orizaba and Popocatapetl; farther west still lie the volcanoes of Jorullo.

The volcanoes of Java and Sumatra lie in a line parallel with the principal axes of these islands. The former, instead of lava, pours forth during its eruptions vast quantities of mud and ashes; the mud is supposed to originate from the materials within the mountains themselves, in consequence of the action of the hot acidulated waters and acid sulphureous vapors generated in the bowels of the

mountains. These vapors destroy or reduce to a pulp all rocks with which they come in contact.

The vertical section of a volcanic mountain shows that its rocks have been rent by fissures. These run in different directions, and intersect each other. These fissures have been filled with molten matter, and hence the appearance resembles a net-work of dykes

Volcanic action, in the main, is due to the residual heat of the interior of the earth. Hence the force is deeply seated, or is known to issue from below the granites. No doubt the fires are seated among those materials which have never cooled. A theory which is based on any other foundation would not explain the immensity of volcanic operations.

210. It is only in the Cainozoic era that the common phenomena of volcanic action can be recognised. Neither cones nor lava proper have been found among Palæozoic rocks. They are traversed, however, by igneous masses, and one of the most extensive trap or green-stone formations, a submarine ejection, was poured forth near the close of the Triassic era.

Volcanic action is not accompanied with the same phenomena at different times, neither do different volcanoes eject the same kind of materials during different eruptions. At one time it is a thick heavy lava, which flows from one or two sides of the crater. The volcanoes of the Sandwich Islands, according to Professor Dana, are boiling pools of melted rock; excavations, rather than craters, and their activity is accompanied with moderately loud explosions, and the shrill hissing of steam issuing from a boiler.

211. The moon's surface, when seen through a good telescope, appears to be studded with volcanic mountains; so distinct, indeed, are its craters that their interiors are clearly revealed. In all respects the lunar volcanoes resemble outwardly the terrestrial ones, only it presents them in forms and numbers which greatly exceed those which now exist upon its surface.

212. *Earthquakes.*—A phenomenon which stands in direct connection with volcanic action is the earthquake. It consists, essentially, of movements of the earth's surface in the form of waves, or undulations, which travel with great rapidity in all directions from the focus of disturbance. These waves are due, no doubt, to a shock arising from the explosion of elastic bodies pent up in cavities, and analogous to the explosions in coal mines, only immensely more powerful. They precede and perhaps continue during the

first outbursts of volcanic forces. The intensity of this movement, or force of the shocks communicated to the strata, is supposed to be in some way dependent upon the diameter of the vent through which the gases and melted matter finally escape. The throat or chimney through which the volatile matters, lava, &c., escape from Vesuvius, Etna, and the South American volcanoes, is narrow or constricted, at the same time the arch above the subterranean cavities is thickened and strengthened by immensely heavy deposits of lava, &c. Hence, under these circumstances, volcanic forces are confined by strong walls; and hence, when the forces have acquired strength sufficient to rend asunder these walls, or force the safety-valve, it will be attended with tremendous earthquake shocks. On the other hand, where there is a wide opening for the escape of the highly heated matters, as in the volcanoes of the Sandwich Islands, where the craters are rather wide, and similar to excavations, volcanic action begins and goes on without such violent shocks as to endanger the surrounding country. The shock of the explosions communicates to the crust an impulse which generates a wave, which usually moves onward and outward with great velocity. The surface rises and falls like the waves of the sea; or, in other words, the undulations travel onward with great speed, in obedience to the ordinary law of a force propagated through a resisting medium.

The undulation, however, is modified by the position and condition of the resisting medium. In its progress, a direct undulation may be converted into a gyratory one, by an increased resistance in its course, or into a vertical one, at the place situated immediately above the point of impulse. Considering earthquakes as earth-waves, it is evident that when those waves are generated in the ground beneath the ocean, their impulse must be communicated to the water above, whose motion will partake of the same character. Waves will therefore be generated therein, which will travel onward in the direction which the impulse communicates; but from the nature of the medium the water-wave will travel with less speed than the earth-wave. In consequence of this fact, a person upon the shore where two waves are tending, will perceive first the earth-wave, and soon after the water-wave will follow; lastly, another wave will be recognised through the medium of the air. In each of these cases the rate of transit depends on the nature of the medium which receives the shock.

213. The effects upon the earth's crust are worthy of particular notice, especially with reference to the change of level which it undergoes during an earthquake paroxysm. The coast of Chili, for example, during an earthquake in 1822, was permanently elevated for one hundred miles; in some places more, and in others less than ten feet.

214. In concluding this branch of the subject, we remark that the student will sooner or later perceive that geological history necessarily embraces two great fields of investigation: 1. *Physical Geology*, including the dynamics and statics of geology; and, 2. *The history of the development of the organic kingdoms*, including palæontology, or the description of the vegetables and animals belonging to the strata. Each furnishes distinct fields of research, but the highest generalizations grow out of the mutual relations discovered between the physical movements and vital forces in activity during the geologic periods. The influence of the physical forces or the crust movements upon the organic kingdoms, has ever been exhibited in a strong light, and they seem to stand in the relation of cause and effect. But however this may be, we see in the great series of movements the constant operation of *natural causes* in opposition to *miraculous ones*, in which respect the phenomena of the *physical world* stand in contrast with the *organic world;* for in the latter we have necessarily to recognise the constant interference of a miraculous power in the creation of new organisms, to replace those which have become extinct. The process of extinction, it is true, may be in obedience to a natural law; but there is in operation no law by which *life force* is imparted to matter, except through the special and direct will of the Creator. There is no spontaneous evolution of life-forms from matter, but all life-forms, through all the vast geologic periods, must be attributed to the act of one Will, in whom only life can emanate.

It will strike any one, especially the palæontologist, that organic forms are constantly varying. Each system has its own fauna, each has its own history, though it is not independent. But he will be particularly struck with the contrast which the Palæozoic world furnishes when compared with the Cainozoic; and this contrast will place in its true light, the progress the world has made in passing from a Palæozoic to a Cainozoic age.

CHAPTER XXIII.

MINERAL VEINS—VEINS OF ROCK OR EARTHY MATTER.

Fig. 217.

Lead Vein of Rossie, N. Y.

215. A VEIN is a sheet of mineral matter traversing a rock, or series of rocks, more or less obliquely, and sometimes nearly, if not quite, parallel for short distances, at least, with their component lamina or strata. The relation of these sheets to the rock which they traverse proves that they were formed after the latter was consolidated.

In accounting, therefore, for their formation, it is necessary to recur to the former high temperature of the earth, and to employ that well known elementary fact, the contraction of matter during cooling, in order to explain the origin of fissures in its crust. The matter in a vein differs from that of the adjacent rock, and the boundaries are usually so distinct, that the mass of the sheet may be separated from it, though in some cases the cohesion is so great that in the attempt the adjacent rock is also broken away. The rock in contact with the sheet of the vein is called the wall. The vein

is, therefore, bounded by two walls: the foot wall below, the hanging wall above. The obliquity of the sheet varies from verticality to a nearly horizontal position, for a limited space. A vein is often quite flat at its outcropping; in its descent it becomes more vertical, a fact which seems to affect its richness, inasmuch as steep veins are more loaded with metal than flat ones.

We have represented a vein as a sheet of mineral matter; it should be stated that it is not like a sheet—equal in thickness throughout—but quite variable in this respect, bulging out in some places and contracting in others.

216. A vein, again, is composed of the vein stone and the metal intermixed with it, lying in favorable veins somewhat in subordinate sheets parallel with the walls; in other cases it is scattered through the gangue or vein stone somewhat irregularly. In the most favorable veins the metal lies upon the foot wall.

217. The kind of gangue or stony matter associated with the metals of a vein is generally quartz in the auriferous and copper veins of North Carolina—these veins, however, sometimes contain calcspar. But numerous minerals occur as vein stones, as sulphate of barytes, and sometimes strontian, as at Rossic, N. Y., fluorspar, carbonate of iron, associated with quartz, as at several copper mines in North Carolina, and sometimes epidote.

The direction which the veins of this country pursue is northerly and southerly, varying in this respect from nearly north-west to north-east, or north 70° east.

218. The descent of the vein is never direct and unbroken. It is made up of many nearly isolated sheets or tracts of mineral matter. A superior tract overlaps the inferior in front, and it thins out at its inferior edge, while the inferior sheet, at its superior edge, falls back against the foot wall.

The entire sheet of a vein is not equally rich in mineral matter. Thus the auriferous vein of Gold Hill is traversed by rich tracts of auriferous metal, which alternates with poor tracts. This is true of veins in Europe. It is necessary in such cases to find the rich auriferous tracts. The gold is not entirely absent in the other parts of the sheet—they are simply poorer. None of the metals appear to be confined to a certain rock. Gold, for example, occurs in the argillaceous and talcose slates; in hornblende and serpentine, though rarely, and sometimes in a limestone gangue; and it is found in remarkably rich deposits in quartz rock of sedimentary origin, which is equivalent to the quartz rock of Berkshire Co.,

Mass. The presence of metals seems frequently at least to be dependent upon a store of the material in the region beneath. The same rocks which are metalliferous on the east side of the Blue Ridge, are less so on the west side.

Veins differ in Age.—Most of the metals are found in the pyro-crystalline rocks, and when the veins occur in sediment they are not removed very far from them.

219. Fissures are, no doubt, filled in different modes. The matter which fills a fissure must have been either liquid or aeriform, the material being always crystalline, and frequently in the condition of perfect crystals. Hence it is probable they are filled from beneath, and not by sediments washed in from above.

It is not difficult to conceive that a fissure which extends to that depth where the materials are molten, that the forces generated there would be sufficient to fill the fissure with liquid matter. Dykes, no doubt, are filled with matter in this condition, the fissure extending to the depth required. But it is more consonant with facts, and the nature of metalliferous lodes or veins, to infer that the sulphurets and chlorides especially have been introduced in the condition of vapor, the fissure becoming really a gallery of sublimation. This view is sustained by arguments derived from the incandescent state of the interior. But fissures exist which might be termed *blind fissures;* that is, they are neither connected with the incandescent part beneath, nor the earth's surface above. A fissure with no opening in any direction, will not remain empty. To such a point the hygrometric water of the rock will tend, bearing its most soluble matters in solution. Such a fissure would be a vacuum, and hence could not fail to receive and also be filled with the soluble matters in the course of time. The filling of such cavities is usually regarded as due to an electric agency, which, it is supposed, may operate through a considerable mass of rock.

Veins are irregular in width; sometimes enlarging to twice or thrice their average width, or they may contract.

Veins are shifted also from their regular range or direction. The shifted parts frequently preserve their parallelism. Dykes are usually found crossing those veins when thus thrown out of their regular strike.

CHAPTER XXIV.

MEAN ELEVATION OF LAND—OCEAN LEVEL—DISTURBANCES, OR DISLOCATIONS OF THE EARTH'S CRUST—EPOCH OF SOME OF THE MOST IMPORTANT DISLOCATIONS—GRADUAL AND PAROXYSMAL ELEVATIONS—RELATIONS OF LAND AND WATER—CHANGES OF TEMPERATURE INDUCED BY A CHANGE OF RELATIONS, AND EFFECT ON THE DISTRIBUTION OF PLANTS—THE RELATIONS OF IGNEOUS ROCKS TO DISTURBANCES OF THE EARTH'S CRUST.

220. *Mean Elevation of Land and Ocean Level.*—The first impression respecting the mean elevation of land above the level of the ocean, probably is that it is much greater than the truth, as it is known that some points of the Himalaya and Andes rise from twenty-five to twenty-eight thousand feet. This impression is subsequently corrected by the consideration that the area, which is covered by water, is more than three times greater than that of the dry land, especially when taken in connection with another fact, that the mountain areas are less than one-half that of the level and undulating parts of its surface. Certain small tracts of land are beneath the level of the ocean, as the valley of the Jordan and the Dead Sea, the latter of which is some 1300 feet below the level of the Mediterranean. But the few instances of extreme depths of gorges of this kind affect but slightly general results, or the general conditions of the earth's surface. The mean elevation of surface for England, Wales, and Scotland is about 500 feet. It is estimated, however, that the mean elevation of land for Asia and America, in round numbers, is about 2000 feet. This estimate, however, is probably too great. The ancient doctrine, once quite prevalent, that the level of the ocean was inconstant, and subject to great fluctuations, has given place to the more consistent view, that its variations in level are but slight, or so limited, indeed, that no variation can be detected beyond the rise of tides; hence the mean level of all oceans is a constant, of a given value, and subject to no perceptible variation, while the elevation of land is a variable quantity.

The elevation of land, however, is not so great but that its whole area might be covered with water; and were all the continents submerged, the ocean level would not be raised five hundred feet above its present tidal line.

221. *Disturbances, or Dislocations of the Earth's Crust.*—The elevation of land is no doubt due to the action of forces beneath. This view is suggested by many well-determined facts; for example, the immediate connection of intense volcanic action with mountain chains, and the phenomena of the invariable increase in the number and extent of dislocations as we approach the axes of the mountain systems. One of the general effects of dislocation and disturbance of the earth's crust is to displace the ocean; for example, the effect of the elevation of the great Rocky Mountain range has been to displace the Atlantic from its base and the Mississippi Valley. The Atlantic has therefore travelled eastward, in consequence of which North America has been reclaimed from the dominion of its waters.

222. The epochs, when dislocations have taken place, is well worth our attentive study. That there have been periods of intense intestine commotion, which has resulted in fractures of the earth's crust, and which has been followed by periods of rest, is well determined. The general result of inquiry is, that mountain systems have been formed at different epochs. Some are much older than others, and, what is remarkable, the highest of our mountain systems upon the globe are the youngest. The Alps and the Himalayas belong to the Tertiary epoch, while our Alleghanies belong to a period just subsequent to the Carboniferous. The later disturbances may affect all the previous systems of rocks. It will be upon the upturned edges then of the older masses that new deposits of sediments will be formed.

The disturbance which elevated the Carboniferous rocks of Pennsylvania, and even placed the older in a leaning position upon the newer, affected the whole series of rocks in the valley of the Hudson, and caused the slates to override each other. Phenomena of this kind may be witnessed in the streets of Troy, and the railroad cuttings in the vicinity of Albany. The Devonian of Pennsylvania at Pottsville rests or leans upon the coal measures.

The most ancient disturbance which occurred in the sedimentary period, was just subsequent to the termination of the Taconic epoch. This is evident from the fact that the oldest members of

the Silurian rocks rest upon the upturned edges of the Taconic series throughout the upper part of the valleys of the Hudson and Lake Champlain.

During the Tertiary period the disturbances which affected the Atlantic coast may be regarded simply as oscillations of the land. The most important or most extensive movements of the earth's crust, within the time specified, were in immediate connection with the Drift period. These movements have already been described.

In considering the character of these movements, we can scarcely avoid the conclusion that *some*, at least, were violent and paroxysmal, though in the later periods they were quite limited, and resemble those which occur during earthquake movements, an example of which was witnessed in Chili, in 1822, when its coast was elevated ten feet for one hundred miles at least. The valley of Lake Champlain presents phenomena which indicate paroxysmal movements in lines of parallel ridges, and which point to the former levels of the waters which occupied the present valley.

223. We have already alluded to the fact that the dry land is variable in position and height, and that these changes occur without affecting the mean level of the ocean. It is, however, important to state that such changes exert considerable influence upon the temperature of a country. The snow-line of continents, or the line of perpetual frost, is about 15,000 feet, under the equator, above the level of the sea. This line constantly approaches the earth's surface towards the poles. But the rate of approach to the earth is influenced by the nature of the surface. High land causes it to descend more rapidly than plains, and especially if the surface is covered with water. Water surface is favorable to the production of moderate temperatures; and as a water surface favors also a moist atmosphere, the kind of vegetation grows out of certain combinations of land and water surfaces.

In accounting for the distribution of plants, however, it is necessary to consider dryness as well as temperature and moisture. Certain plants occupy certain zones of height and latitude. It is found that height compensates for latitude, and that what are termed Alpine plants occur also in high latitudes. Saxifrages and mosses flourish upon mountain slopes and high latitudes. Northern woods furnish birches, beeches, pines, and willows. High meadows, the gramineæ and the cyperaceæ, or the coarser grasses. Such

facts are important elements in geological inductions, but we have no space to dwell particularly upon the subject.

224. The geographical areas of belts or zones of disturbances often seem to be connected with the distribution of certain igneous rocks. Thus the green-stones of the Trias form a prominent feature of the period in this country. The Palisadoes of the Hudson, the traps of Mount Holyoke and the Connecticut Valley, are connected with disturbances and oscillations of this epoch. These igneous rocks form a less bold feature in Virginia and North Carolina, but still they traverse the same series in heavy dykes. The anthracite region, however, of Pennsylvania, though greatly disturbed, appears to be an exception to the rule. We find neither granite nor trap in immediate connection with the coal measures. So distant are the masses of igneous rocks that it is unphilosophical to attribute the debituminization of the coal to the presence of this class of rocks, or to the agency of heat in the interior of the earth.

225. The general distribution of heat upon the earth's surface is not altogether controlled by latitude. The mean temperature of a given degree of latitude in Europe is higher than that of the same latitude in America. Lines of equal temperature, in Europe, when prolonged to this continent, turn southward, and change their direction at least 10 degrees. Lines indicating equal temperatures are called *isothermal.*

226. The distribution of animals is governed in part by temperature. Climatal conditions, however, embrace many elements. All parts of the earth's surface bring forth plants. Marine animals occupy greater ocean depths than plants.

The occurrence of large fossils and animals in northern latitudes was an enigma, until it was discovered that they were provided with a covering suitable to their habits and requirements. Thus, the extinct Siberian elephant was covered with a dense coat of coarse wool and hair; and hence, too, we may conclude that fossil species were as well provided for as those which are familiar to us, and belong to our own times.

CHAPTER XXV.

SOILS.

227. SOILS are mixtures of earths, oxides, salts, and vegetable mould, or matters derived from decomposed organic substances, to which we may add water and air. As a body, then, they may be divided into inorganic and organic parts; the former being derived exclusively from the rocks by disintegration, the latter from the vegetable and animal kingdoms; carbonic acid and ammonia were derived from the mineral kingdom. The saline bodies consist of earthy and metallic bases, combined with acids, which are derived from the mineral and organic kingdoms. Phosphoric acid is no doubt derived originally from the mineral kingdom; but in soils its proximate source may be either the animal or vegetable kingdom, or both, in a single sample of soil. Soils, therefore, possess a complex composition, consisting of a large number of bodies, mixed in part mechanically, and in part in chemical combination. The inorganic matters usually predominate greatly over the organic, and of these silica exists in the greatest proportion. To the eye soils appear inert; but we may well believe, from results which we witness, that they continually undergo chemical changes, to which some of the most important results to the agriculturist are due.

As the origin of soils is ascribed to rocks, it will at once be expected that their nature or composition will partake of those materials which are regarded as their source. This is no doubt true in many instances. But it happens that soils have been moved, and do not always rest upon the rock from which they were derived; and hence the exact materials which enter into their composition cannot be decided. Soils, unless the most recent, are rarely in exact situ. The rains, creating a surface drainage, move the lighter parts of soil towards the valleys, where they have been subjected to slow movements for a long time. They finally reach the valleys, and are there spread out.

But the soils, which are now spread over a large part of this country, have been subjected to a more violent movement than we

have just indicated. Thus all of New England, New York, soils and those of the Western States, on the east side of the Rocky Mountains, have been transported from north to south to a distance which has placed them far beyond the limits of the rocks from which they are derived. The effect of this movement has been to mix and blend soils from the different rocks. This movement occurred in the Glacial epoch, of which we have already spoken. But it did not affect large territories in the Southern and South-Western States. Hence, the soil in these states is very nearly in situ, having been subjected to those changes only which are due to common occurrences. It is in this part of our country, then, that the composition of soils partakes of that of the rock beneath; inasmuch as they were derived from it, have not been moved far, nor intermixed with foreign materials.

One important result has grown out of the foregoing fact: the rock having been subjected to the action of those agents which produce disintegration for a long time, beds of soil of great thickness have been formed. The time during which these beds have been accumulating cannot be determined with accuracy; but the process commenced before the last upheaval of the coast, but since the Pliocene period. We are able to trace this formation of soil, by its peculiar red color, to the Tertiary section of North Carolina; and we find it overlying all marine deposits, except the last stratum of sand and pebbles, the latter of which is marine, and forms a mantle over all the deposits of the eastern section of the Southern States. This red layer of soil, which is derived from the rocks of the middle section of these states, may be traced many hundred miles, and it always occupies the same relative position.

From the nature of the origin of soils, from their natural exposures, and especially from cultivation, it is plain their composition must vary exceedingly.

228. For many valuable purposes we may make a geographical division of them.

1. Soils *of the sea coast.* 2. Soils *of interior, occupying plateaus,* and dry slopes. 3. Soils *of valleys,* embracing the alluvium of rivers.

1. *Coast Soils of Marine Origin.*—In the Southern States, beyond the action of the forces displayed during the Glacial epoch, the soils may be divided into sands, clays, mixtures of these ele-

ments, and those of vegetable origin in part, together with a mixture of vegetable matter and sand, with some clay.

The sands occupy the surface of large tracts of country, as the pine barrens; but while the surface was still covered with the ocean, or at the time of its recession, large tracts of surface materials were carried away, and the country was denuded down to a bed of marine clay. The marine clay is on the east side of the heavy beds of sand, which presents an undulating surface not unlike the sea when agitated. These sands contain from 88 to 95 per cent. of silex, or rather sand, in rounded particles. Often they are pure enough, after washing, for glass, perhaps with the exception of some magnetic iron sand. This sand is more or less intermixed with vegetable mould, and even in its poor condition supports a forest of long-leaved pine. But it does not bear cultivation; and when put under the plough it soon wears out and blows into ridges, and whole regions, underlaid with these sands, would drift and become movable sand banks. When, however, it contains clay, it is comparatively a good soil.

229. The most important kinds of soil are those in which vegetable matter is very large, exceeding, in a few instances, 90 per cent.; that is, it becomes strictly peat. But the percentage of vegetable matter is variable, and when it does not exceed 75 per cent., and is intermixed with from 10 to 25 per cent. of earth, it forms the best of soils. Soils composed of this large percentage of vegetable matter can be found only in swamps.

There are two kinds of swamp lands; the first has its due proportion of earth, as the swamp lands of Hyde and Onslow, North Carolina; the second has too small a proportion of earth to admit of tillage, as the open prairie of Carteret county, near Beaufort.

230. The composition of the Hyde county lands is as follows:—

Organic mattter,	48.10
Silex,	43.00
Oxide of iron and alumina,	6.40
Carbonate of lime,	0.50
Magnesia,	0.30
Potash,	0.26
Soda,	0.18
Chlorine,	trace
Soluble silex,	0.03
Sulphuric acid,	0.04
Phosphoric acid,	0.60
	99.31

The inorganic matter, after the removal of the organic, is extremely fine, and of a light drab color. This is the condition of all the good swamp soils. It appears to have been originally matter suspended in water, and these swamps, producing the ordinary growth, sphagnums, mosses, &c., were often covered with water arising from freshets in the neighboring streams, and which then overflowed, depositing, during the time, a fine sediment amidst the marsh-growing vegetables. This variety is therefore of fresh-water origin. But the open prairie land, or soil, is swamp, less advanced, or received no sediments from the rise of rivers; or, in other words, they were never overflowed with waters charged with debris, or sediments; they contain or produce the coarse vegetables and grasses, but have no earth or soil proper.

Associated with the foregoing we believe it possible to recognise another variety still, which was due to marine influences. Thus, a poor soil, consisting of a white sand intermixed with black vegetable matter, is common in the low counties of North Carolina and other Southern States. It looks, before cultivation, like the former, but in a few years it becomes decidedly sandy; the black mould is burnt out, and the marine sand begins to blow into ridges. It is unproductive after a few years of cultivation.

231. The marine clays and mixtures of sand resemble, in all respects, the clays of the uplands. They are good wheat soils, while certain varieties of the swamp lands are the best for Indian corn, producing steadily from fifty to sixty bushels per acre per annum for a century, without the use of fertilizers.

232. The soils of the interior, occupying terraces and slopes, are usually dry, gravelly, and silicious. The terraced valleys of the rivers of New England and New York, the bluff formation of the river valleys of the Western States, possess these common characters. They are formed in some instances, by the gradual displacement of the soil from the steep hillsides, and accumulating in the valleys; but being in the direction of a watercourse, they are cut through, and worn down in process of time, leaving the lateral parts of the beds standing in the form of terraces and bluffs. The bluff soils and terraces are sometimes the recipients of springs from the mountain sides, and hence they are less productive at first, being too cold for the best grasses, or for the cereals. Drainage is necessary, and is easily effected. It cures the difficulty, and these terraced valleys become the most valuable soils of the country.

233. The productiveness of all soils depends upon the presence of all the elements enumerated in the foregoing analysis. But the farmer or planter is under no necessity of supplying but a few in this list. Of those which disappear after cultivation, the alkalies and alkaline earths, and phosphoric acid, are the most important. These never exist in large quantities. It appears, too, from observation and experiment, that they may exist in the soil in such a state of combination that they are inaccessible to the roots of plants, or, in other words, are locked up. The atmospheric agencies, however, are always at work, and when a soil is allowed to rest, they accumulate in perceptible quantities.

The productiveness of any soil is affected by its temperature. Wet soils are unsuitable for the cultivation of the cereals. Hence the necessity of drainage.

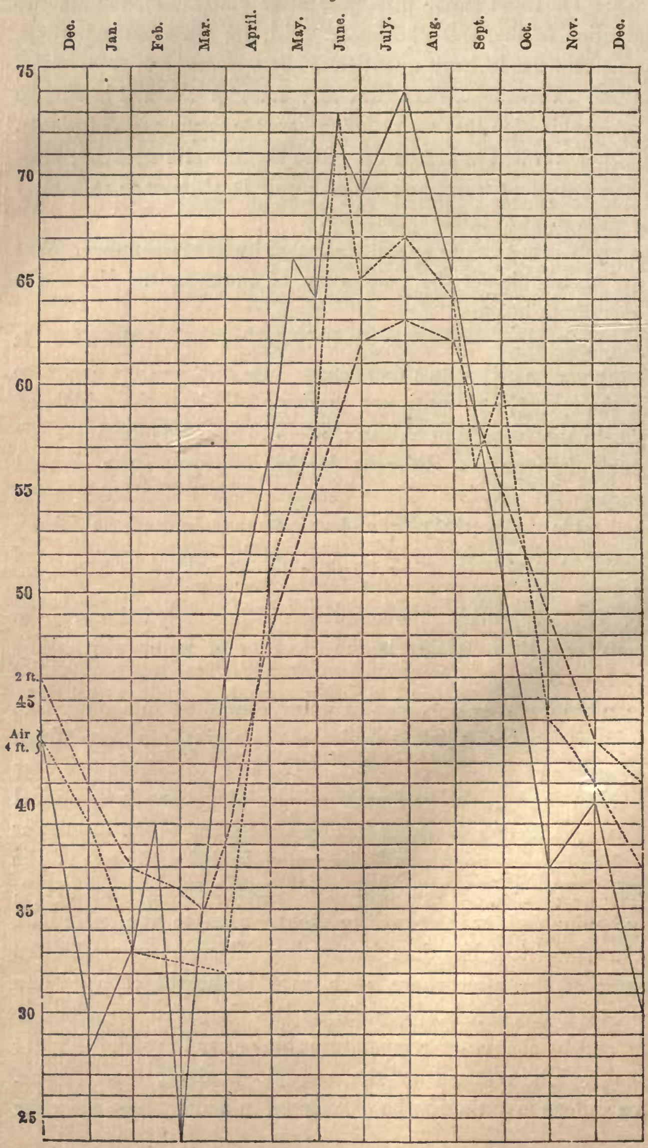
234. The temperature of any soil is due to solar influence. It is continually changing in this respect. Its temperature begins to rise in the spring, and continues to rise until about the middle of August, in the latitude of Albany, when it gradually declines. It is affected differently at different depths, undergoing the greatest change near the surface. These changes are well exhibited in the annexed table. (Fig. 218.) The observations were made at Albany for three years in succession by myself, and the results are expressed in the mean for every two weeks during the year 1847.

235. There is still another condition which greatly influences the productiveness of soils. It is the quantity of water which they receive from the atmosphere.

The usual quantity of vapor or water contained in a cubic foot of air, is four grains, which is equivalent to a pint in a room fifteen feet square and eight feet high. A column of atmosphere over each acre of land holds one-fourth millions of gallons in its normal state, without feeling damp, or having a tendency to fall in mist or dew. But this quantity may be increased in different parts of the columns. Thus, during the warmth of summer temperature (70°), it may be doubled, or increased to eight grains to the cubic foot, while in winter it is less than four grains. If we assume a limited thickness of the atmosphere, each yard of height of a column whose base is one acre may contain no less than sixteen gallons of water; and by change of temperature this power of retaining water may be rapidly reduced to the normal standard, four gallons. Twelve gallons may thereby be discharged in a short time upon the

Semi-monthly observations on the mean temperature of the soil at Albany, taken at different depths, for 1847 *: viz., air represented by a continuous line ; two feet and four feet, by dotted lines. The marginal numbers are the degrees of temperature. Months at the head of the columns.*

Fig. 218.



surface of an acre. But clouds are well-known accumulators of vapor, which is originally dissolved in transparent air, but becomes visible by partial condensation. An acre of cloud, five hundred yards thick, may discharge any quantity of water, up to six thousand gallons, provided the air in regard to temperature varies from 70° to 40°.

If a cloud, five hundred yards thick, moves at the rate of three miles an hour, and deposits one twenty-fifth part of its available water, there will be a shower of rain, and the quantity marked upon the rain-gauge will correspond to one inch, and will therefore amount to twenty thousand gallons to each acre which it passes over at the assumed rate of three miles to the hour.

The quantity of water in a soil varies very much with its composition. Sandy ones contain less than clay soils, but a soil well constituted as to fertilizing matter, is always tenacious of moisture. The most tenacious of water are those which contain a large intermixture of very fine organic matter; next to these are the marly clays. The moisture or water of soils may be husbanded by early planting, or by securing an early growth of the plant sufficient to cover and shade the surface during a time of drought.

236. Soils may be too fine to be productive, on the ground that their compactiveness excludes the access of air. The extremely fine-grained soils, formed from sediments alone, would be too compact if not intermixed with organic matter, as those of Hyde county, North Carolina, and certain soils of the Western States. Coarse soils, as those of some of the New England States, decompose slowly, and may furnish in a given time too small a quantity of potash and phosphoric acid, and the other expensive elements, for steady cultivation. They require rotation and rest. The effect of stones in a soil is to condense moisture and preserve it in a favorable condition for the growth of vegetables.

237. Certain green crops, used as manures, bring to the surface the expensive elements which are beyond the reach of the roots of cereals. Clover roots, as well as the southern pea, send their rootlets deep, and thereby open the soil.

238. Ploughing, when the soil is wet, is injurious, because the soil breaks up in large coherent lumps, which become hard on drying, and an entire season is required to break them down.

Deep ploughing brings up virgin soil nearer the surface where it is acted upon by the air, and better prepared to furnish nutriment to the plant.

329. *Soils of Mountain Slopes absorb Caloric.*—Independent of the color of the surface, the soils of mountains become warmer by the absorption of heat than those of plains at or near the sea level. Hence, the snow melts which is in immediate contact with the earth, and forms an arch (which protects Alpine plants) while they bloom and perfect their seed. So, among the snow-covered summits, the radiant heat melts the snow beneath, and preparative of a sudden descent of the avalanche upon the plains below.

Even the hill-sides of New England become green at an earlier day in the spring than the low meadows which surround them. It is in consequence of the law of the absorption of heat, by mountain sides and slopes, that they are so well adapted to the pasturage of cattle, and the production of numerous plants.

The effect of absorbed heat upon vegetation may, however, be counteracted by excessive moisture. This state arises from the numerous springs which issue from mountain sides: the surface water being absorbed by and retained in the soil, preserves it in great excess; and hence, when it evaporates, it cools the soil by absorbing its extra heat it has absorbed from the sun's rays.

240. The soil derived from particular rocks is to a limited degree characterized by the composition of the parent rock. All trap rocks form a good soil, because they are more or less charged with alkalies, alkaline earths, and the phosphate of lime. So, on the other hand, granites, which are coarse and contain much quartz, make a poor soil, because its texture is open, and the soil is poor in the elements furnished by trap; and yet certain granites, rich in feldspar, make good soils. These may be known by their red color, which they acquire by exposure to the atmosphere. As a general rule the soils derived from granite, gneiss, mica slate, and hornblende rock, do not differ essentially in composition. The soils they furnish are generally strong and durable. The mountain soils of New England furnish many varieties and examples. They are excellent for grass. It has been supposed that soils which rest upon limestone are necessarily charged with a larger percentage of lime than those which rest upon gneiss or granite. In my "Agriculture of New York," I have shown by many analyses, that this is not the case. But it is to be recollected that all parts of New York have received large instalments of drift, which has been derived from many sources. The drift covers limestone as well as gneiss. But there is a class of rocks which impart their own character to soils which rest upon

them. They are the fragile slates and shales which are constantly undergoing decomposition; and it frequently happens that the debris which is thus formed is reached by the plough, and is freely intermingled with the old and partially-exhausted matters. Large tracts are common in the Mohawk Valley, especially in Central New York, over which the Clinton and Onondaga salt groups are extended.

241. Climate influences soils, however, to such a degree that they often seem to lose the characteristics derived from the parent rock. This, however, becomes more perceptible after long cultivation. Where the climate is not well adapted to grass, the surface is greatly disposed to gully and wash. Besides, the surface is liable to be carried away by rains, and it becomes naked and presents a barren appearance. Such is the condition of large tracts in the Southern States. The gullies, however, are often created by a wrong system of ploughing, that of running furrows down the hill-side.

One of the most important points to be seen to by the planter and farmer, is, to keep the surface protected by vegetation. More injury is done to a soil by being permitted to be naked and exposed to the washing by rains, than by a judicious cultivation.

242. Another important point to be attended to in cultivation, is the condition of the soil when ploughed as to the presence of water. As a general rule, soils filled with water should not be ploughed; and it is also true that a soil in very dry condition should not be ploughed. It is well known that if a soil is ploughed when wet, it becomes lumpy and hard, and the effects may sometimes be seen for two or three years.

243. The evils attending wet soils are obviated, at least in part, by deep drainage. The effect of drainage is to open the soil, increase its porosity, and make the heat absorbed from the sun's rays useful in the cultivation of the most valuable crops. To the farmer who drains his lands, spring arrives two weeks earlier than to his neighbor who neglects it. But the results of drainage are not limited to the spring; early planting secures an early harvest. He escapes the frosts of autumn, while the drought of summer is ameliorated by the early growth of his crops. A good and early stand is often the turning point of the planter's hopes. Ground which is shaded by corn early in summer rarely suffers destructively by excessive droughts.

NOTES.

NOTE A.—p. 89.

The remarks which appear in the Regent's Report of New York, for 1859, require a brief notice.

The slates or shales referred to in northern Vermont, as constituting a new series above the so-called Hudson River group, instead of ranking thus high in the geological scale, are really sub-silurian, as is fully proved by the overlying calciferous sandstone. The latter rock, though it is not known to contain fossils in this part of the state, yet in many places in New York it does; particularly a species of Maclurea (Straparollus), where the same relations exist as at Bald Mountain. The mistake arises from the variable character of the calciferous sandstone, though its general aspect is preserved, even when it is chocolate colored, and it might be suspected to be the true representative of this silurian member. These colored masses, however, pass into the common variety, when it often contains the lower silurian fossils. But the slate has never furnished a silurian species. We now know the following trilobites, all of which belong to a slate beneath the calciferous, viz.: Atops punctatus, eliptocephalus (Paradoxides) asaphoides, Paradoxides Thompsoni, P. Vermonti, P. macrocephalus, Paradoxides (Pagura) quadrispinosus, and Microdiscus quadricostatus. None of these occur in the Hudson River slate or shales. To get rid of difficulties, it is said in the report referred to, it is designed to make a new group of strata, which, it is maintained, occupy a position above the Hudson River shales. The impropriety of such an arrangement, must be admitted by all candid and well-informed geologists, since the calciferous sandstone overlies this slate.

NOTE B.—p. 190.

It is maintained by a few distinguished geologists, that the life of corresponding ages in Europe and America is older in the latter than in the former. Before this doctrine is accepted, it should be subjected to a more rigid scrutiny than it has yet received; for down to, and including the carboniferous era, there are no facts which countenance this assumption. It is admitted by the highest authority that the carboniferous era corresponds in the life ages in the two continents. Progressing downwards another great stage, the Permian, the correspondence is still preserved. A comparison of the cretaceous system of Nebraska, Kansas, Texas,

Alabama, New Jersey, and North Carolina, will force upon geologists the conclusion that a correspondence in life is still maintained in both continents. The same conclusion is sustained with respect to the miocene—a conclusion founded in part on the presence of fossil plants belonging to the genera, Populus, Liriodendron, Laurus Sapotacites, &c. This conclusion has been sanctioned by Professors Heer, Leidy, Marcou, and several other geologists of high standing. So, also, in the formation called drift, we find identical fossils, as at Quebec, and Udder valley, in the north of Europe. If, then, the foregoing conclusions are true, it would be quite remarkable to find an exception in the Trias. The probability is, that on both continents strata of considerable thickness may and do exist on one continent, which are not represented in the other, even when a formation coincides generally in age.

GLOSSARY OF SCIENTIFIC WORDS.

Abnormal. Contrary to law. An unusual developement of structure or form.

Acephala, Acephalous. Without a head; a Cuvierian class of mollusks or shellfish, as the oyster and clam.

Acicular. Needleform.

Acrogens. Plants which grow from their summits, as the ferns.

Affinity. In Chemistry it is that force by which elements combine and form new compounds. In Zoology it is used to express genealogical relationship.

Agamic. Infertile, as the ova which have not received the male influence.

Agate. Uncrystallized quartz whose parts are arranged in bands of different colors and shades.

Agatized. Arranged in bands like agate.

Algæ. Cryptogamic marine plants or sea weeds.

Allotrophy, Allotropism. The property of existing in two or more states or forms, as oxygen in ozone its active, and common oxygen its passive state.

Alluvium, Alluvion, Alluvial. Beds of sand and gravel which are now accumulating along the banks of rivers and lakes.

Alumina, Pure clay. *Aluminum,* The metal or base of alumina. *Alum stone,* A mixture of iron pyrites and clay. Shales are often alum stones.

Amber. A fossilized resin, common in tertiary beds.

Ambulacra. The rows of holes or prominences in the shells of Echini or Echinoderms.

Ammonite. An extinct genus of Cephalopoda. They have coiled, chambered shells.

Amorphozoa. The sponges, or the least organized class in the animal kingdom.

Amorphous. Devoid of a regular geometric form; uncrystallized.

Amphibia. A class of animals with naked skins, as the frog, toad, and salamander.

Amphineust. Reptiles which are provided with both lungs and gills, as the siren and proteus.

Amphipoda. A small tribe of crustaceans, supplied with fourteen slender feet, similar to the sand flea.

Amygdaloid. A porous variety of trap; or trap which had originally almond-shaped cavities, and into which, in process of time, infiltrations of silica and the silicates took place, as agates, carnelian, phrenite, &c., &c.

Analogize. To find resemblances between things belonging to diverse types.

Analogue. The theoretical representatives belonging to diverse types; thus, the order Raptores, in the class Birds, are the analogues of the highest carnivora in the class Mammals.

Analogy. In Natural History it is the similarity in function which exists in organs belonging to dissimilar types, as the fin of a fish and the wing of a butterfly, the lungs of a mammal and the gills of a fish; hence it is said there exists an analogy between the gills of a fish and the lungs of a mammal; but there is no homology.

Anamorphosis. The changes which genera undergo in their course through time.

Anatifa, Anatifæ. Pedunculated cirripeds; they are barnacles supported on stems or peduncles.

Angiosperms. Plants whose seeds are enclosed in a capsule.

Angle. A corner, or the inclination formed by the meeting of two or more planes or lines.

Anisomeric. Consisting of dissimilar parts; unsymmetrical.

Antennæ. The jointed thread-like organs belonging to the heads of insects.

Anthozoa. Marine animals resembling flowers. A general name applied to zoophytes, coral, &c.

Anthracite. A hard, debituminized coal.

Anthropoid. Resembling man. Applied to monkeys which most resemble him in externals.

Anticlinal, Anticlinal axis. The dipping of strata in opposite directions.

Apod. Without feet.

Araucaria. Applied to a family of pines, mostly confined to South America and New Holland; they differ in structure from other conifers in having the dots in two or three rows arranged alternately.

Arborescent. Branching like a tree.

Archetype. The perfect representative of a form or group of forms.

Archimedes Limestone. One of the subordinate beds of the lower Carboniferous series.

Arenaceous. Sandy; a friable variety of quartz.

Arenicolites. Worm holes in sand and sandstones.

Argillaceous. Clayey; composed in part of clay.

Articulata. The *Second Branch,* or type, of the Animal Kingdom.

Articulated. Jointed.

Asteroidea. Star fishes; an order of Echinoderms.

Atolls. Coral islands of a circular form, and which are bounded by a rim of coral enclosing a lagoon.

Atoms. Particles of matter which cannot be further subdivided.

Avalanche. Falling masses of snow from mountain peaks or sides.

Azoic. Without life.

Azoic age. An age prior to the existence of life upon the globe.

Back. Miner's term for joint.

Bala limestone. In Wales, a limestone belonging to the Cambrian system and equivalent to the Trenton in New York, or at least in part.

Basalt. A black, compact variety of trap without visible particles of pyroxene, felspar, or hornblende.

Base line. A line taken as the foundation of operations in trigonometrical and geological surveys.

Basin. A depressed area with the strata dipping inwards.

Bed. A layer of rock of a uniform character, as a bed of coal, clay, or sand.

Bedding. The position of beds in a group of rocks; the bedding may vary from the horizontal to a vertical position.

Belemnite. An extinct genus of Cephalopods.

Bench. In surveys, a selected plane or bed which is to be, or may subsequently be, referred to.

Bi. When used as a prefix denotes two or twice.

Bilateral. Having a right and left side.

Binomial System of Nomenclature. A system which recognises the principle of giving two names to objects composing the kingdom of nature, as FELIS *tigris*, ACER *rubrum*, &c., first employed by Linnæus.

Bitumen, Bituminous. Mineral pitch; a highly combustible substance, exhaling when burnt a peculiar odor.

Blastema. The primitive basis of an unformed organ.

Blende. Blackjack of miners; a compound of sulphur and zinc.

Bluff. A bold bank of deposits along the shore of rivers and lakes, inclining steeply on the water side.

Botany. The science which treats of plants.

Bottom Prairie. A formation first noticed by Prof. Swallow; so named to distinguish it from the high land prairie.

Botryoidal. Resembling a bunch of grapes.

Boulders. Blocks of detached rocks, which are more or less rounded by attrition. They are sometimes called *travelled* rocks.

Branches, in zoological classification, imply the four grand divisions of the animal kingdom, viz., Vertebrata, Articulata, Mollusca, and Radiata.

Branchial. Belonging to, or serving the office of gills.

Breccia. A mass composed of cemented angular fragments of rocks.

Bryology. The science which treats of the true mosses.

Bryozoa. Moss-like animals; a sub-class of mollusks.

Buck. In mining, to break or pulverize ores.

Cænozoic. The formations, as the tertiaries, which contain the highest organic bodies or remains. As the mammals.

Cainozoic. Recent life.

Calcareous, Calciferous. Containing lime.

Calcareous sinter. Calc sinter. A porous deposit from spring water consisting of lime and carbonic acid.

Calcareous, or *Calcspar.* Crystallized carbonate of lime.

Cambrian System. A name proposed by Prof. Sedgwick, of the University of Cambridge, Eng., for the Lower Silurian System.

Canon, Canyon. A deep gorge bounded on each side by steep banks or cliffs.

Capsule, Capsuliferous. Bladder-like organs; bearing capsules.

Carapace. The shield which covers the back in turtles, or the front part of a crustacean.

Carbon. A simple combustible body. Coal is an impure example, and the diamond is pure carbon.

Carbonates. Combinations of carbonic acid with a base, as lime, iron, lead, &c.

Carboniferous. Bearer of carbon; a name given to a system of rocks which contain beds of coal.

Carbonic Acid. A gaseous unrespirable compound of oxygen and carbon; choke-

damp of miners, and accumulates in dry wells and depressions. It is poisonous to inhale, and suddenly deprives a person of the power of moving. Dashing a pailful of cold water upon the subject is the true remedy.

Cataclysm. A violent flood; a deluge.

Caucasian. A name applied to the white races of man, which are supposed to have originated near Mount Caucasus; the Indo-Europeans.

Cell development. The evolution of cells or growth of cells in organic structures. A reproduction of cells.

Cellular. Formed of cells, and, when uncompressed, appear like little sacs.

Centre of Gravity. A point which if supported, a body will remain at rest.

Cephalic. Pertaining to the head.

Cephalopoda, Cephalopods. Organs of motion, feet or arms arranged around the head. A class of mollusks occupying the highest rank in this branch of the animal kingdom.

Cetacea. Marine mammals, as the whale, porpoise, &c.

Cetotolite. Os petrosum, or ear bone of a whale in a fossil state.

Chalk. An earthy limestone occupying the upper part of the Cretaceous System.

Chalybeate. Chalybeate springs; water holding iron in solution.

Chambered. Shells which are provided with transverse partitions, as the ammonite.

Chert, Cherty. A massive silicious rock closely resembling flint; mixed with chert.

Chemung Group. Rocks of the Upper Devonian System, and which take their name from the county of Chemung, N. Y.

Chimeræridæ. A family of sharks with cephalic appendages.

Chouteau Limestone. A limestone belonging to the Upper Devonian System. Observed in Missouri, and first described by Prof. Swallow. Occurs in Cooper, Boone, and Marion counties, Mo.

Ciliæ, Ciliated. Minute vibrating organs somewhat like hairs; furnished with ciliæ.

Cleavage. The property of splitting with regularity in certain directions, in contradistinction from breakage. In geology it is often applied to the splitting of slaty rocks in a direction contrary to the plane of deposition, in consequence of which the cleavage planes are often mistaken for the planes of deposition.

Cliff Limestone. A limestone in the western states occurring in cliffs. It is found to be an erroneous designation, as it embraces two limestones. One Devonian, equivalent to Corniferous limestone, and the other Silurian, equivalent to the Calcareous beds above the Trenton.

Climatic. Pertaining to climate.

Coal Formation. Any series of rocks containing beds or seams of coal.

Coalescent. Joined together; running together.

Compressed. Flattened sideways.

Conformable, Unconformable. When the planes of different strata of different ages are parallel, they are said to be conformable. If strata rest on upturned edges, they are unconformable. Degrees of unconformity exist.

Conchoidal. A fractured surface resembling the curvatures of a shell.

Concretion. A mass assuming a rounded form, whose particles combined when the rock was in a plastic state.

Condyle. The protuberances at the base of the skull upon which the head moves in a vertical plane.

Confervæ. Water plants which consist of tubular jointed threads.

Congeners, Congeneric. Species which belong to the same geuus.

Conglomerates. Beds which consist mostly of pebbles, and which have passed into a consolidated state under water.

Coniferæ. Cone-bearing trees whose seeds are naked, as the pines.

Conjugation. In physiology, it is the sexual union of the infusoria or plants which produce spores; the intermingling of the contents of cells.

Convolute. Rolled together like the cypræa.

Coriaceous. Leathery.

Corallum. The solid or calcareous parts of a polype.

Correlation. Having reciprocal relations. Relations of things and beings which are dependent on something previously existing; relations of the són tó the father are correlative.

Cosmical. Having reference to the universe of matter and the harmonious laws which govern its movements; the term may be restricted to the solar system.

Cosmogony. Speculative views respecting the origin of the globe.

Costeaning. A Cornish term applied to a particular mode of searching for metallic bodies; as the sinking of shallow pits, or driving tunnels across the formation.

Cotyledon. In botany, the lobes ðf seed, as occurring in the bean or pea.

Crag. An English term for a shelly deposit of the tertiary age.

Crater. The funnel-shaped opening at the summit of a volcano, and from which volcanic matters issue or have issued.

Cretaceous, Cretaceous System. Belonging to the chalk; a system of rocks which closes the Mesozoic period.

Crop, Crop Out, Outcropping. The appearance at the surface of the strata of any series of rocks. They sometimes form a mere selvage, or appear at their edges.

Crustacea, Crustaceous. A class of Articulates which are covered with a species of corneous crust, as crabs, shrimps, lobsters, &c.

Crust of the Earth. That part of the earth which is accessible to observation.

Cryptogamia, Cryptogamic, Cryptogamous. A great branch of the vegetable kingdom which produces *spores* instead of *seeds*, and which are flowerless, as sea weeds, mosses, ferns, and lichens.

Crystals, Crystalline, Crystallized. Bodies which are bounded by regular geometric planes; an assemblage of coherent grains or masses of rock of imperfect forms.

Cycadeæ, Cycads. A small order of naked-seeded plants belonging to warm climates. Their stems are short and stumpy, with pinnate leaves, and inrolled like the ferns.

Debacle. A rush of waters carrying forward debris and broken fragments of rocks.

Debris. The disintegrated portions of rock in place, or moved from the parent bed by frost and atmospheric agents.

Deduction. In logic, that which is drawn from premises. A conclusion supported by facts or principles.

Deciduous. Falling of organs at a given or certain period.

Delta. The land enclosed by the forks of rivers where they enter the sea, and which are usually of a triangular shape.

Dentine. The bony part of teeth directly beneath the enamel.

Denuded, Denudation. Rocks or surfaces stripped of their former covering by a rush of waters.

Depressed. Flattened from above.

Dermal. Pertaining to the skin.

Desmidian. A family of microscopic plants of a green color, arranged somewhat in the form of a chain.

Determination. The application of the characteristics to minerals and plants, fossils and rocks.

Detritus. Matter worn from rocks by mechanical action.

Dextral. Applied to shells whose spires turn from east to south.

Diatom. A microscopic silicified plant, made up of cells divided into two halves or valves. A family of Diatoms.

Dicotyledons. A grand division of plants whose seeds have two lobes.

Dichotomous. Dividing into two branches.

Didelphis. A marsupial quadruped, or one with a double uterus, one of which is formed by a fold of the skin of the abdomen.

Differentiation. In physiology, a development by a process of evolution; as when a reed develops roots and stems, it is called a development by differentiation. Or applied generally to the growth of organic bodies, it is an evolution from pre-existing bodies, as from the stem.

Diluvium. Ancient beds of gravel and boulders, and which have been spread over the earth by water, or by water and ice. These beds were formerly regarded as having been formed by the Noachian deluge.

Dip, Angle of Dip. Inclination of strata towards any point of the compass.

Discoidal. Like a disk, applied to univalves. Where coils lie in one plane.

Disintegration. The separation of the component particles of a mass through the influence of water and the atmosphere.

Ditrematous. Having two openings; a mouth and a vent.

Dolomite. A limestone containing a large proportion of magnesia.

Dorsal. Belonging to the back.

Drift. Transported beds of gravel, sand, &c.

Dunes. Low hills of blown sand which skirt the shores of Holland, France, and England.

Dykes, or *Dikes.* Narrow sheets of rock which fill ancient fissures, and which run in nearly straight lines; they often project above the surface like walls, and hence their name.

Earth's Crust. Those parts of the earth which are accessible to human observation.

Ecpyrosis. Destruction by fire.

Echinoderms. A class of Radiates whose external envelope is spinous or subspinous.

Elvan. A Cornish name for an intruded rock, in composition between a porphyry and granite.

Embryon, Embryo. The rudiments of an animal while in the womb, before its membranes are visible, and from which we have the following terms: Embryology, Embryogeny, Embryography, Embryotic.

Enaliosauria. Sea lizards or marine saurians, whose organs of locomotion are paddles.

Encrinites. An order of Echinoderms which are supported upon a jointed column.

Estuary. Bays at the mouths of rivers where the water is only brackish.

Encrusting. Spreading on surfaces like a crust.

Endogens. Inside growers; a large and important class of plants whose woody fibres are disposed in bundles, and whose stems have neither bark nor a proper central pith. Their seeds have only one cotyledon, and their leaves are provided with parallel veins or nerves. Examples: Indian corn, the grasses, bamboo, sugar cane, reeds, &c.

Eolian. A formation of recent origin, consisting of a marine sand drifted and arranged by the wind.

Epidermis. Outer skin.

Epoch. The time when an event happened.

Era. A period comprehended between two fixed points.

Escarpment. Abrupt slopo.

Evertile. Capable of being turned inside out.

Exogens. Vegetables whose trunks or stems grow by additions to tne outside.

Extensile. Capable of being lengthened.

Exuviæ, Exuviation. The cast of the coat or crust of a crustacean; the laying aside of the old coat or crust.

Faluns. A French provincial name for those tertiary beds which are of the age of the Norfolk crag.

Family. Genera grouped together by likeness.

Fault. The sudden interruption of the continuity of strata, accompanied with a displacement on one side.

Fauna. The aggregate species of the animals which are peculiar to one country.

Felspar, Felspathic. A simple mineral of a sparry appearance; one of the constituents of granite; a rock mixed with felspar.

Ferruginous. Containing oxide of iron or its salts.

Fertilizers. In agriculture, substances which promote the growth of plants, directly or indirectly.

Filament. A slender thread; part of a stamen.

Fire-fangled. A manure which has lost a large part of its value by excessive heat and fermentation.

Flags. Thin, even beds of rocks which readily separate along the plane of deposition. They may be arenaceous, argillaceous, or calcareous.

Flora. The plants peculiar to any region or country taken in the aggregate.

Fluccan, Fluckkan. The softened walls of metallic veins, which have disentegrated to a pasty or powdery mass, with little coherence remaining.

Fluviatile. Belonging to a river.

Fluvio Marine. Deposits formed at the mouth of rivers by the joint action of the sea and river.

Foliaceous. Leafy; bearing leaves.

Formation. A series of beds which belong to one epoch; or a group of rocks associated by organic affinities and by geological position.

Fossil, Fossiliferous. The remains of plants and animals belonging to any geologic formation; fossil-bearing rocks.

Frontal. Placed on the front.

Fucoid. A family of fossil plants resembling sea weeds.

Galena. A mineral compound of sulphur and lead.

Ganglion. A knot; an enlargement in a nerve.

Ganoine. The bony tissue immediately beneath the enamel of the scales of Ganoids.

Gasteropoda, Gasteropods. A class of mollusks whose locomotive organ is attached to the belly.

Gem. In mineralogy, an order embracing the ornamental stones, as diamonds, sapphires, &c.

Genetic. Relating to origin.

Genus. A group composed of allied species.

Geode. A spherical cavity lined with small crystals.

Glacier. Vast accumulations of granular snow or ice, covering Alpine regions, and which on declivities move slowly to the plains below, bearing forward, at the same time, the debris of the rocks of their mountains.

Gneiss. A laminated pyro-crystalline rock, often, but incorrectly, stated to be stratified.

Gossan, Gozzan. The hydrous peroxide of iron, mixed more or less with decomposed rock; the former is derived from the sulphides of iron, or copper and iron. The depth of the decomposition depends upon the depth where water is constant.

Granite. A massive pyro-crystalline rock composed usually of quartz, felspar, and mica.

Granulated, Granular. Reduced to grains; made up of grains.

Grauwacke (nearly obsolete). A German name for some of the members of the Palæozoic rocks.

Greenstone. Trap, composed of hornblende and felspar.

Green Manure. Formed of a growing crop of clover, rye, peas, or some other vegetable, and turned under by the plough.

Gregarious. Associating together in numbers, or in flocks.

Green Sand. The lower cretaceous beds containing particles of silicate of iron.

Grit, Grits. A sharp-grained sandstone; or beds of angular or rounded quartz.

Gymnosperms. Flowering plants with naked seeds.

Gypsum. Plaster of Paris; sulphate of lime; a mineral composed of sulphuric acid and lime; a valuable fertilizer, and accompanies rock salt and brine springs.

Gyrogonites. The spiral seed vessels of plants belonging to the order Characeæ.

Hamilton Group. A series of dark-colored beds occupying a middle position in the Devonian system.

HO. Chemical symbol for water; the initials of hydrogen and oxygen.

Homogeneous. Of one substance.

Homologue. The similarity of structure in organs: as the wings of birds and the paddles of the whale. It is also applicable to individual parts: as a particular bone in the hand of man is the homologue of one in the paddle of a whale, and hence, homologize is a process by which homologies are determined. In this connection we have homologous, homologically, homological.

Homology. Relations which exist in organs belonging to one type of structure, as the arm of a man and the foreleg of a horse.

Homomorphous. In botany, similarity in shape.

Hornblende. A simple mineral of a dark green color, and is also a member of the laminated pro-crystalline rocks.

Hydro. As a prefix, has reference to water.

Hypo. As a prefix, means under or beneath, and scarcely differs from *infra.*

Hypogenous. Originating below.

Hypozoic. Below life. The name applies to gneiss, mica slate, hornblende, &c.

Hornstone. A massive grayish variety of quartz which has the lustre of horn; and is also tough, breaking usually with a large conchoidal fracture.

Hudson River Group. The shaly and slaty varieties of rock, and some sandstones, above the Trenton limestone; and which are poorly represented in a few places in the Hudson River Valley. The designation turns out an improper one, though very generally used.

Humus. Vegetable mould; a dark brown vegetable matter, intermixed largely with new or uncultivated soils.

Iceberg. A mass of floating ice originating in the polar regions. They bear debris, and distribute it over the bottom of the ocean along the course over which they float.

Ichnology. The science which treats of the footprints of extinct animals.

Igneous Rocks. Rocks which have been acted upon by the internal fires of the earth, and which have been forced to the surface in the condition of molten matter, as trap, lava, &c., including granite.

Increment. Augmentation by addition, and not by evolution from pre-existing parts.

Individuals. The units belonging to the different kinds of existences.

Inductive Science. Associated facts strung together, or so combined, as to enable us to discover causes.

Inorganic. Without organs, and which are independent of vital action, as minerals, the mineral kingdom.

In situ. Unmoved, or in the place where formed.

Inter. As a prefix denotes between.

Invertebrata. Animals without vertebræ.

Isothermal. Lines along which the temperatures are equal.

Joints. The planes indicated by lines on the faces of many rocks. These lines become visible by the slight separation of regular-shaped masses from each other. They lie obliquely to the bedding planes.

Kaolin. China clay, or clay arising from decomposing felspar.

Kibble. A large bucket for elevating ore.

Lacustrine. Produced by or belonging to lakes.

Lamellibranchiata. Shell fish provided with lamellar gills; as clam and oyster.

Lamelliferous. Made up of thin plates like paper.

Laminæ, Lamination, Laminated. Thin crystalline plates into which a rock may be divided. Laminæ proper are never made up of rounded grains, or embrace fossils.

Lava. The molten rock derived from a volcano.

Lias, Liassic. An English provincial name for the lower strata of the Jurassic system.

Lignite. Carbonized wood which retains its original structure.

Limit of Activity. The size or bulk at which an organism loses its power of locomotion.

Linear. Like a line, or long and slender tissue or organ whose sides or margins are nearly parallel, as the leaves of grasses.

Lite. As a suffix relates to stone, being derived from *lithos,* a stone.

Lithological. Used to express the mineral character of a rock or formation.

Lithographic Stone. One suitable for lithography.

Littoral. A zone between high and low water in zoological geography.

Loess. A name given to a post-tertiary formation upon the Rhine.

Longitudinal. Arranged lengthwise.

Loricated. Reptiles furnished with dermal bony plates.

Lycopodites. Fossil plants closely allied to the club mosses or ground pines. The Lycopodiaceæ is a natural family of flowerless plants ranking with ferns and the vascular Cryptogamia.

Madrepore. A family of corals distinguished by superficial star-shaped cavities.

Magnesian Limestone. Any limestone which contains a definite quantity of magnesia. It is also an English name for a member of the Permian system. We also apply it to the calciferous sandstone, as it always contains magnesia. A *dolomite* is a granular variety of magnesian limestone, differing in structure from the preceding. If, however, any of these magnesian rocks are locally granular, or rather coarsely crystalline, they are described as *dolomitic.*

Mammalia. The highest grade of vertebrates, and which suckle their young.

Mammoth. An extinct species of the elephant; the fossil elephant of Russia.

Mammillary, Mammillated. A surface formed of rounded projections, which are segments of a sphere.

Marl, Marly. A mixture of fine and incoherent carbonate of lime with some clay and sand. If it becomes solid it is sometimes called indurated marl.

Marsupialia. A class of mammals provided with an external pouch for lodging their young, as the opossum and kangaroo.

Mastodon. An extinct pachyderm closely allied to the elephant, but its molars are mammillated.

Mass. The whole quantity of matter in a given body or in a given bulk.

Matrix. The bed which a mineral or shell still occupies. The supporting or enclosing matter.

Mechanical Origin. When the origin of a rock is effected by an external force, as water flowing in streams, currents, &c., it is used in contradistinction to rocks which may be said to have a *chemical origin,* or whose particles have been consolidated by a chemical force.

Medial. Passing along the middle.

Mesozoic. Middle life.

Metamorphic Rocks. Those which have been altered since they were consolidated. Rocks undergo a limited change by the influence of heat from a trap dyke. There is no proof that ordinary gneiss, mica slate, &c., are altered sediments.

Metamorphosis. Change of form by which a caterpillar or larva becomes a fly, a chrysalis, or a butterfly.

Mica Slate, Mica Schist. A rock composed of quartz and mica with a thin laminated structure, and usually fissile through the mica planes.

Mineralogy. The science which treats of minerals.

Miocene. The middle division of the Tertiary. A minority of its mollusks are living in our seas.

Molasse. A series of tertiary beds in Switzerland.

Mollusca, Molluscous. One of the great branches of the animal kingdom, embracing those animals which have soft bodies like the clam and oyster.

Mono. As a prefix, denotes single or one; as monodelphic, one brotherhood.

Monogeneric. Oneness of origin.

Monotrematous. Having but one opening to the body which serves for a mouth and vent; or one orifice for urine and fæces.

Moraine. The debris of mountains brought down to the valleys by glaciers, and which is arranged in ridges.

Morpho. As a prefix, relates to form.

Morphology. The science which treats of the forms of the organs or parts of animals or plants.

Motile. Possessing the power of self-motion without will or consciousness.

Mountain Limestone. The lower or older beds of the Carboniferous system.

Muriate of Soda. One of the chemical names for common table salt.

Muschelkalk. The middle member of the Triassic system. A marine calcareous deposit.

Mycology. The science which treats of mushrooms.

Nagelflue. A conglomerate rock belonging to the Tertiary of Switzerland.

Natatory. Formed for swimming.

Naturalism. A pantheistic creed which claims to be founded upon natural phenomena, maintaining that all that exists is simply a succession of phenomena. It is destitute of religious elements.

Neocomian Stage. Lower green-sand, according to some English geologists.

Neozoic. Formations more recent than the palæozoic.

Neptunian. Aqueous deposits.

Néve. The highest part of a glacier.

New Red Sandstone. One of the common names for the Triassic system.

Nodule. A rounded mass, formed by a molecular force and destitute reticulated veins of foreign matter.

Normal. Ordinary, or as a body usually appears; according to law.

Obsolete. In natural history, obscure, indistinct.

Oid. As a suffix, indicates similar to, or like another object.

Old Red Sandstone. A member of the Devonian system.

Onondaga Limestone. It takes its name from Onondaga Co., N. Y. It is the limestone member of the Devonian system.

Oolite, Oolitic. A limestone made up of roundish grains similar to the roe of a fish. It is also a rock belonging to the Jurassic system.

Operculum. The plate or valve-like body which closes the mouth of univalves.

Ophidia. An order of reptiles containing the serpents.

Oral. Belonging to the mouth.

Organic, Organized. Having organs; produced by vital action.

Organic Remains, Fossils. Remains of animals and plants in sedimentary rocks.

Orthocerata, Orthoceratites. Mollusks belonging to the class Cephalopoda, whose shells are straight and chambered.

Osar. Ridges of stone, and in which is mixed gravel and sand.

Oscillations. Movements to and fro, like the pendulum of a clock.

Osteology. That part of anatomy which treats of bones.

Otolites. Ear-bones of fishes.

Outliers. Isolated strata which are now found at a distance from the main body of the formation to which they belong.

Ovate. Egg-shaped.

Oxide. A combination of oxygen with another body, as iron, forming a compound called an oxide, as the oxide of iron in the condition of iron rust.

Oxygen. A simple gaseous body which supports respiration and combustion. It is a constituent part of the atmosphere and water.

Pachydermata. An order of animals with thick skins, as the elephant, tapir, and extinct mastodon.

Palæozoic, Palæozoic Rocks. Ancient life; a division of rocks which terminate upward with the Permian system. This division contains no species of animals or plants which are now living.

Palæontology. The science which treats of fossils.

Palates. Crushing teeth of sharks and rays.

Palliobranchiata. Mollusks furnished with a pallium or cloak, and which performs the office of gills.

Paragenesis. To be present with, or the co-existence and mode of association of mineral bodies.

Parasite. Living on animals as their home or residence.

Pectinated. Set like the teeth of a comb.

Pelagian, Pelagic. Belonging to the deep sea.

Petroleum. A liquid mineral pitch and highly combustible.

Phænogamous, Phænogomic Plants. A branch of the vegetable kingdom, all the individuals of which bear flowers and seed, as the rose, tulip, Indian corn, grass, &c.

Pinnæ, Pinnate. Processes set in rows like the beards of a feather.

Pit Coal. So called originally because it was obtained by sinking pits in the rock or ground.

Placer. A name given to deposits of gold.

Plaginyona. With lateral muscles.

Plastic Clay. A clay of the lower Eocene period; so called from its moulding properties. The term is nearly obsolete.

Pleistocene. Most recent.

Pliocene. The third division of the Tertiary series. The proportion of living mollusks is greater than the extinct.

Plutonic, Plutonic Rocks. A name applied to granite rocks originating below by the agency of heat, some porphyries, &c. They are supposed to have been perfectly fused, and to have consolidated and crystallized from that condition.

Poicilitic. Variously colored, variegated; a term applied to the red, blue, and green marls of the Triassic system.

Poly. As a prefix, indicates many.

Polyzoary. The united mass of many Polyzoa organically connected.

Porphyry, Porphyritic. A submarine pyro-plastic rock which contains crystals of felspar in a compact base. Any rock is porphyritic which has crystals of felspar in a compact base, or one which approaches this condition.

Pre. As a prefix, denotes before; as pre-glacial, before the glacial period.

Precipitate. The matter separated from a solution by a reagent, and which subsides to the bottom of the vessel; any fine matter which separates and finally subsides to the bottom in the condition of a fine powder.

Prehensile. Capable of catching hold.

Primordial. Existing from the first.

Pro. As a prefix, means before.

Proboscidian. An order of mammals provided with a proboscis or trunk, as the elephant.

Proto. As a prefix, denotes first; as protozoa, first life.

Protozoic. First life.

Pseudo. As a prefix, implies something false; but its meaning is modified by the subject to which it applies.

Pterichthys. A winged fish belonging to the Devonian period.

Pterodactyles. Flying lizards.

Puddingstone. A pebbly bed consolidated in the air.

Pumice. A porous lava which floats on water.

Purbeck Limestone, Purbeck Beds. A fresh water deposit belonging to the Wealden of England. It contains many small extinct mammalian remains.

Purposive. In doctrine, it implies any change which is for a purpose.

Pyrites, Iron Pyrites, and *Copper Pyrites.* Compounds of sulphur and iron, or sulphur, iron, and copper. The first is sometimes called *fools' gold.* In North Carolina it is generally auriferous. It is one of the most generally diffused metallic compounds known.

Pyrogenous. Originating in fire.

Quadrumana. Four-handed; an order of mammals including the monkeys.

Qua-Qua-Versal Dip. Beds which dip to all points of the compass.

Quartz, Limpid Quartz, Quartz Crystals. It is a pure form of silex, or nearly so.

Quartzite. A rock consisting mostly of amorphous quartz, sometimes in the form of chert or hornstone.

Race. The descendants of a stock. It may be used generally, as the race of Adam, or restricted, as the race of Abraham.

Racking. In mining, the separation of broken rock from earth by shaking in a frame.

Rake Vein. A sheet of mineral matter or vein standing nearly vertically, and quite uniform in thickness.

Ratio. The relation which one quantity bears to another.

Re. As a prefix, means repetition.

Reptatory. Creeping; creeping animals.

Rhizopod. Feet extending out like roots and thrust out at will. A microscopic animal of the lowest grade. Most species occupy multicellular shells, and are called Palythalamia.

Rodentia, Rodents. An order of animals provided with two cutting teeth in each jaw, shaped like a chisel.

Roth-todt-liegendes. The oldest rock of the Permian system, and so called by the German miners. It is a red sandstone beneath the Keuper Schiffer.

Row Culture. In agriculture, cultivation of crops in drills or rows.

Rubble. A fragmentary rock, slightly decomposed, which overlies certain quarries of rock, so called by quarry men.

Ruminantia. An order of animals which chew their cud or ruminate, as the ox, deer, &c.

Saccharoidal. White and granular like loaf sugar.

Saccharine. The sweet taste of sugar.

Salses. Eruptions of mud or of vapor accompanied with the escape of heat.

Saltatorial. Moving by leaps.

Sarcode. A peculiar form of soft, fleshy, extensile matter of the rhizopod, no distinct tissue.

Sauria, Saurians. An order of reptiles containing both the scaly and loricated families. Alligators.

Scar. A bold precipice of rock nearly equivalent to the term bluff.

Schist. It is often used as a synonym for slate; slaty.

Seams. Thin layers, or sheets of mineral differing in kind from the enclosing rock.

Secondary, Secondary Rocks. The name is now applied to the same division of rocks as the Mesozoic.

Section. A face of rocks exposed by nature or art, represented in a drawing.

Sediments, Sedimentary Rocks. All materials which have been deposited under water, or by its instrumentality.

Septæ, Septum. A partition between cavities.

Septaria. Roundish masses of limestone checkered internally and sometimes externally, and traversed by seams of spar dividing the mass into angular parts. They are formed in rocks, while the materials are still in a plastic state, by molecular attraction. These masses undergo, during farther consolidation, a shrinkage which forms cracks, and which are subsequently filled by calcspar or barytes, &c.

Sessile. Without footstalks.

Shale. A consolidated clay less firm than slate; it is sometimes bituminous.

Shell Marl. A deposit of clay containing lime and shells.

Shingle. The sands and gravel of a sea beach.

Shoding. To trace out veins by fragments of ore upon the surface.

Silex, Silica, Silicious. A combination of silicon and oxygen; it is the pure earth or pure quartz, and is the most common mineral substance in nature. It resists for a long time the action of atmospheric agents. It forms the framework of the globe.

Silt. The finest sand transported by water, and which accumulates at the mouths of rivers.

Silurian. A name given by Sir Roderick I. Murchison to a system of palæozoic rocks well developed in ancient Siluria, a kingdom once inhabited by the Silures on the border of Wales.

Simple. In chemistry, an undecomposed body. In mineralogy, one that is homogeneous.

Sinistral. In shells, turning from east to north.

Sinter. A deposit from mineral springs; it may be calcareous or silicious.

Snow Line. The line of perpetual frost or snow, 15,000 feet at the equator.

Species. The collective individuals which are alike in all their essential characters.

Spermatozoa, Spermatozoum. Singular motile cells in the seminal fluid which impregnates the ovum.

Spherules. Bodies of a globular form.

Spores. The productive germs of cryptogamic plants.

Stalactite. Dependent cylindrical shafts attached to the roofs of limestone caves like an icicle, and produced by the filtration of water through the rock dissolving the carbonate of lime in its progress; a portion of the water drops from

the point, and deposits the remainder of the carbonate on the floor, and there forms a mass which is called *stalagmite.*

Station. The situation in which a species naturally occurs.

Stoping. Mining by removing in layers from above downwards.

Strata, Stratum. Layers of rock which are parallel or nearly so, and which are deposited from water. They lie like the leaves of a book.

Stratified. Debris arranged in strata by water.

Strike. Direction of the outcrop of strata. It is always at right angles to the dip. It is also called the line of bearing.

Styles. Stiff unjointed processes tapering to a point.

Sub. As a prefix, implies under, or used to express diminutions of a quality near to; as sub-equal, nearly equal.

Super. As a prefix, implies above, or in certain cases excess.

Suture. A mark or seam where two edges meet.

Syenite. A kind of granite in which hornblende takes the place of mica. The name is derived from *Syene* in Egypt.

Synclinal Axis. Formed by the dipping of strata towards each other or inwards. It is the opposite of Anticlinal axis.

System. A group of rocks having such relations as to admit or require their union in a systematic classification.

Talus. The fragments of rocks or debris at the base of a cliff; they form a sloping declivity of loose materials.

Taxonomy. In natural history, laws and principles of classification.

Teleology. The science of ends in nature and art, or of final causes.

Tentacles. Slender, contractile, unjointed organs of polypes.

Terrain. The French word for formation.

Tertiary. The youngest great division of sediments.

Testacea. Animals which are covered with a shell or test.

Testudinata. An order of reptiles familiarly known as the turtles.

Thin out. The diminution in thickness in rocks in any given direction, or which may become wedgeform.

Tissues. The soft substances which make up a living body.

Till. Beds of clay with intermixed boulders.

Trap. Igneous rocks which have been projected through fissures or rents in older rocks. Derived from *trappa,* a stair.

Travertin. A deposit of porous carbonate of lime from springs.

Trenton Limestone. A Lower Silurian limestone.

Tri. As a prefix, implies thrice.

Trilobite. An extinct crustacean, generally divided into three lobes.

Truncate. Ending abruptly, as if cut off.

Tuff, Tufa. Volcanic scoria.

Tunicata, Tunicates. A class of mollusks covered with a leathery sac instead of a shell.

Type. The things and beings which combine in themselves the most important characteristics of the group to which they belong.

Umbilicus. The hollow axis of some gasteropods around which the spire is built up.

Un. As a prefix, has a negative meaning.

Unconformable. Strata which have diverse dips.

Under Clays. A term applied to clays beneath a coal seam.

Uni. As a prefix, implies one; as unilateral, one sided.

Veins. Sheets of ore or of minerals unconformable to the beds or lamina of the rock enclosing them.

Vitrification. The conversion of a body into a mass resembling glass.

Vugg. A cavity in a lode.

Waterdog. The common name of the proteus.

Zoid. A cell having motion; as the spermatozoa; or it is applied to an animal in an inferior stage of development; or a single animal in a group of zoophytes.

Zoophytes. A class belonging to the radiates, commonly known as the corals: by some authors it embraces the sponges.

THE END.

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